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Least-Cost Planning Simulation Model

Division of Planning and Local Assistance
California Department of Water Resources

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Least-Cost Planning Simulation Model

LCPSIM Objective

The objective of the use of the LCPSIM with respect to the Integrated Storage Investigations Program is to be able to assign an economic value at the Delta for proposed water storage programs that will allow them to be compared on the basis of their contribution to urban water supply reliability.

LCPSIM Model Concept

The Least-Cost Planning Simulation Model is a yearly time-step simulation/optimization model that was developed to assess the economic benefits and costs of enhancing urban water service reliability at the regional level. The LCPSIM output includes the economically efficient level of adoption of reliability enhancement measures by type, including the cost of those measures. The LCPSIM accounts for the ability of shortage event management (contingency) measures, including water transfers, to mitigate regional costs and losses associated with shortage events as well as the ability of long-run demand reduction and supply augmentation measures to reduce the frequency, magnitude, and duration of those shortage events. Forgone use is the difference between the quantity demanded and the supply available for use.

In the LCPSIM, a priority-based objective, mass balance-constrained linear programming solution is used to simulate regional water management operations on a yearly time-step, including the operation of surface and groundwater carryover storage capacity assumed to be available to the region. The system operations context allows the evaluation of the reliability enhancement contribution of additional regional long-term water management measures, including increased carryover storage capacity, to account for any synergistic interactions between measures. The cost of adding those measures is determined using a quadratic-programming algorithm which minimizes the cost of each incremental addition.

The LCPSIM was designed to be data-driven in order to easily represent different analytical circumstances without changing the model code. If unique situations require recoding, the source has been written with an emphasis on modularity to facilitate this.

Least-Cost Planning Strategy

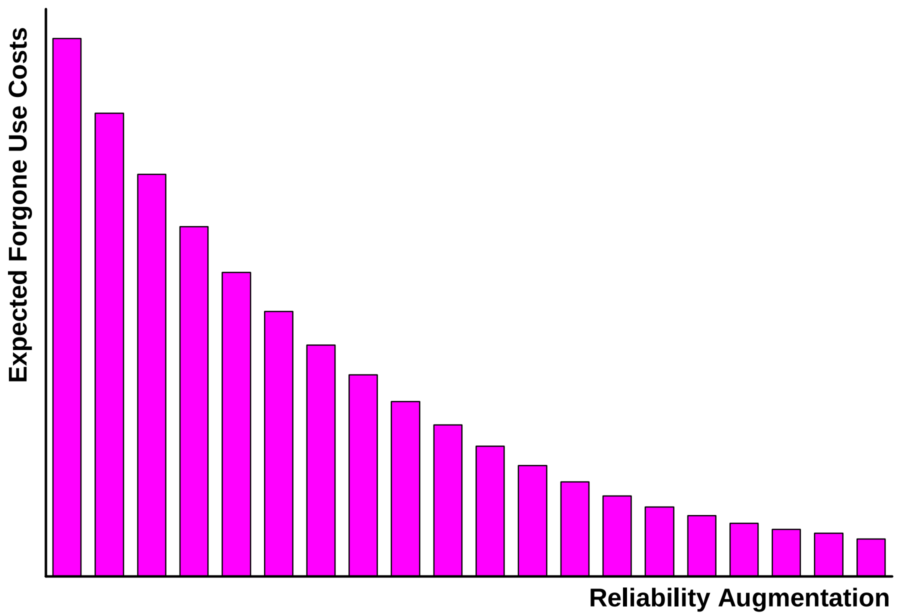
The primary objective of the LCPSIM is to develop an economically efficient regional water management plan based on the principle of least-cost planning. Under this principle, the total cost of reliability management is minimized. This total cost is itself the sum of two costs: the cost of reliability enhancement and the cost of unreliability, recognizing that the latter is inversely related to the former.

Using LCPSIM, an economic value can be assigned to a proposed program to augment imported supplies to a region; such an increase would allow a region to develop a water management plan on least-cost planning principles that would results in a lower total water management cost compared to the circumstances without the proposed augmentation program.

Forgone use is the most direct consequence of unreliability. Forgone use occurs when residential users or businesses, for example, have established a lifestyle or a level of economic production based on an expected level of water supply price and availability for use (i.e., quantity demanded) and the supply availability expectation is not realized in a particular year or sequence of years.

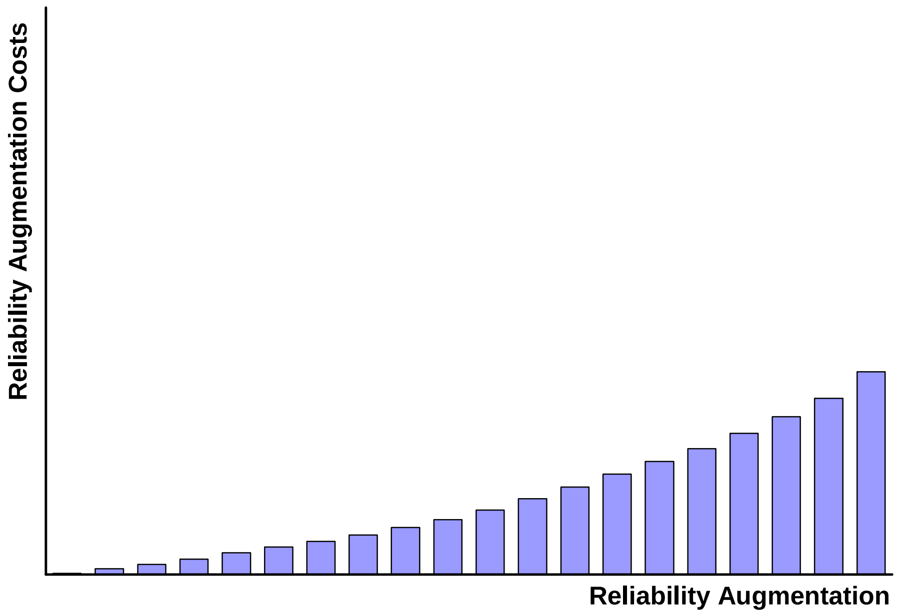
Figure 1 illustrates the expected decrease in the costs and losses associated with forgone use as regional water management options are adopted to enhance reliability. This enhancement may be obtained from either supply augmentation or demand reduction options.

Figure 1. The Effect of Increasing Reliability on Expected Costs and Losses



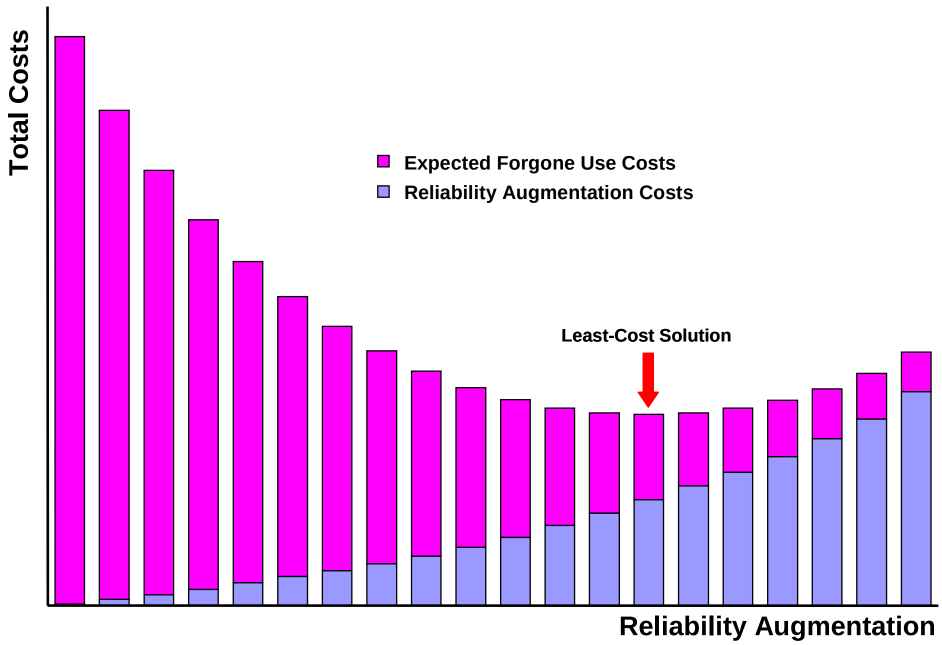
Depicted in Figure 2 is the incremental effect of augmenting reliability on regional long-run water management costs. The assumption is made that options will be adopted in an order inversely related to their unit cost: the least expensive options are expected to be adopted first.

Figure 2. The Effect of Increasing Reliability on Water Management Costs



Shown in Figure 3 is the result of combining the information from Figures 1 and 2 into regional total water management costs tied to the level of reliability enhancement.

Figure 3. The Effect of Increasing Reliability on Total Costs



The least cost solution is economically efficient, that is, it is the level of reliability enhancement beyond which it is economically less cost—compared to the cost of additional reliability enhancement – to accept the expected costs and losses from forgone use. Conversely, at any level of augmentation less than this, compared to the expected costs and losses from forgone use, it is less costly to enhance reliability.

LCPSIM as a Least-Cost Planning Tool

Modeled Relationships. At the least conceptually complex level, the relationship illustrated above related the effect of adopting long-run water management options such as recycling or toilet retrofit programs on costs and losses associated with shortage events. At a more complex level, the availability and use of contingency measures to mitigate the economic impacts of shortage events, such as short-term water market transfers, use of supplies from carryover storage (conjunctive use), and water allocation programs, for example, can affect the economically efficient level of adoption of the long-term water management measures. Conversely, the level of adoption of long-term measures can influence the effectiveness of the shortage contingency management measures and, therefore, their use.

Figure 4. Reliability Management Linkages

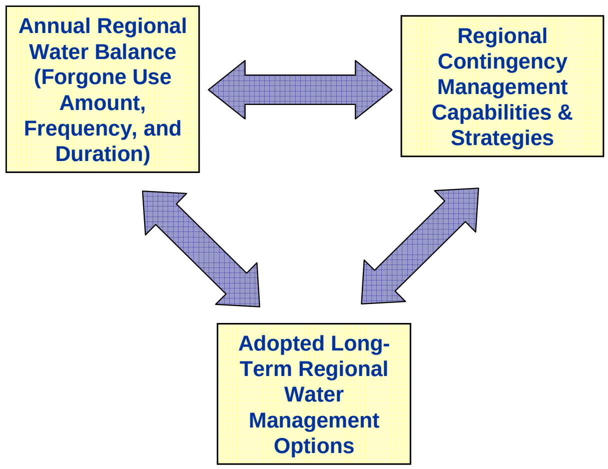
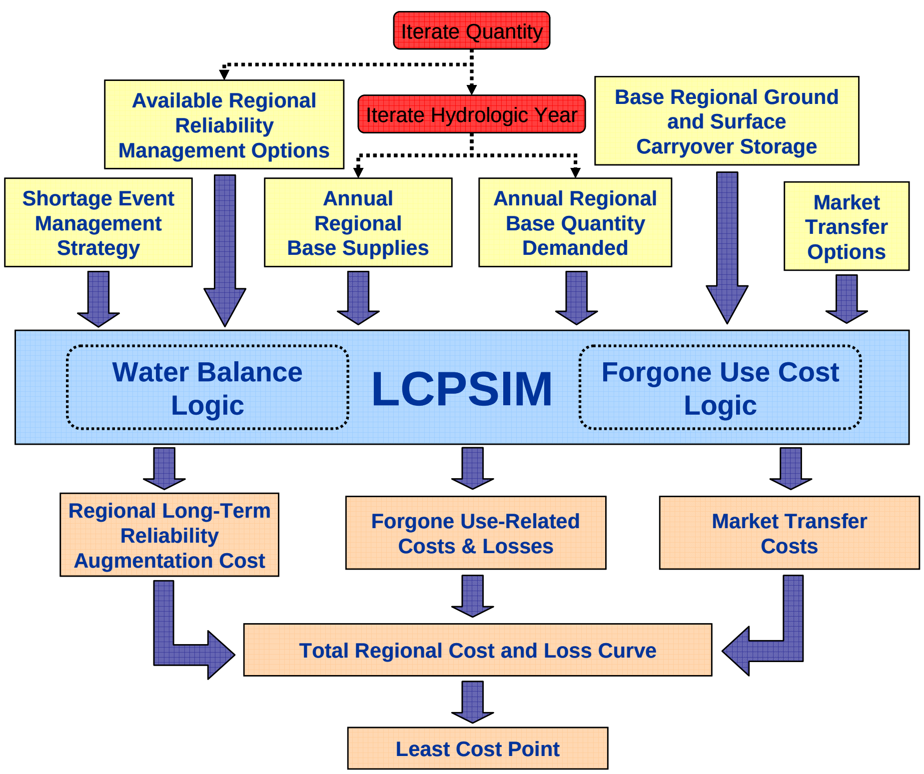


Figure 4 depicts the primary planning interrelationships important for evaluating, from a least-cost perspective, the cost of alternative plans to increase the reliability of a hypothetical water service system. The link between the investment in long-term water management options and the size and frequency of shortages is shown, as is the link between shortage contingency management abilities and the costs and losses associated with forgone use: a greater investment in the ability to manage shortages will lessen the economic costs and losses of due to forgone use when they occur.

The severity of these costs and losses are, in turn, linked to the willingness to invest in long-term water management options. Also, the larger the investment in long-term reliability enhancement, the less frequent and less severe will be the forgone use experienced, reducing the need to invest in the ability to manage shortages. Capturing a system with multiple sources of feedback, such as those which characterize the system outlined in Figure 4, is a complex problem.

Figure 5. LCPSIM Basic Elements



Basic Model Framework. Shown in Figure 5 are the basic elements of the LCPSIM used to generate the total costs and losses curve. This framework was used to attempt to capture the interrelationships depicted in Figure 4 to a reasonable level of realism for the South San Francisco Bay Area and South Coast Hydrologic Region, recognizing the trade off between reasonableness and both input data requirements and model complexity.

LCPSIM identifies the economically efficient level of reliability enhancement provided by long-term water management measures in the context of regionally available shortage contingency management measures. Regional reliability management measures are divided into three categories: (1) shortage contingency demand management (including demand reduction and reallocation of available supplies) and supply augmentation actions; (2) long-term demand reduction and supply enhancement; and (3) economic risk management. The latter strategy involves accepting a degree of economic risk from forgone use in order to avoid the use of other water management measures that are perceived to be even more costly. The least-cost combination of economic risk, regional long-term water management facilities and programs, and shortage management actions is identified within the model for each alternative water management plan being evaluated.

Specific Water Agency Operations Modeled

Modeled operations include deliveries to users, deliveries to and from carryover storage, water transfers, and shortage event-related conservation and water allocation programs.

Carryover Storage Operations. Shortage contingency management measures include the augmentation of current year deliveries with previously stored delivery quantities. In LCPSIM, use of carryover storage is limited to that amount that has been previously placed in storage or declared to be in storage at the start of the simulation. Carryover storage capacity can exist both in surface reservoirs and groundwater basins. The ability to use this storage is modeled using capacity constraints for reservoir and groundwater operations, and annual fill (put) and withdrawal (take) rate constraints for groundwater operations. By default, LCPSIM uses take capacity to stored supply ratios to dynamically set put and take priorities (see *"**Annual Priority-Weighted Mass-Balance Constrained Linear Optimization**"*, below). LCPSIM can trigger water market transfers to refill depleted carryover storage.

> ***Banked Groundwater.*** A banking arrangement may involve an agreement between water agencies in two different regions of the State, for example, allowing one agency to operate a specified portion of the other agency's groundwater storage capacity (e.g. the agreement between the Santa Clara Valley Water District and the Semitropic Water Storage District). The stored water would be water that would otherwise be delivered for use under contract or water right but is stored for later delivery for use during shortage events. LCPSIM has the capability of simulating groundwater bank take constraints such as those agreed upon between MWDSC and the Semitropic Water Storage District and between MWDSC and the Arvin-Edison Water Storage District. The rules for simulating these constraints are stored as LCPSIM data files.
>
> ***Regional Carryover Storage.*** This may be conjunctive use storage that is physically located within the region or it may be located outside of the region (e.g., Metropolitan Water District's Hayfield Project). Storage that uses a federal contract service conveyance facility (e.g., the Colorado River Aqueduct) is constrained by the conveyance capacity available (federal contract deliveries are given priority).
>
> ***Reserve Storage.*** In the South Coast Region, SWP terminal reservoir storage in the South Coast Region can be used for shortage management per contractual agreement. LCPSIM can place strict rules on the use and refill of this storage (i.e., the last to be used and the first to be refilled.)

SWP Carryover. If storage is available in San Luis Reservoir, SWP contractors can elect to have a portion of their SWP supply stored for delivery in the following year when the stored quantity is always assumed to be used to augment SWP deliveries. Available San Luis storage is determined using a file of time series data generated by CALSIM.

Value of Water Delivered to Carryover Storage. LCPSIM assigns an economic value to a quantity of water supply in excess of current quantity demanded by allowing that to be held over in carryover storage to help reduce costs and losses of forgone use during future shortage events.

Conservation and Rationing Operations. These are measures that are instituted during shortage events or when the total carryover storage quantity available to meet a shortage event if it occurs in the following year (or years), is of serious concern.

Contingency Conservation Measures. Examples of contingency conservation measures include: alternate day watering regulations, water waster patrols, emergency water pricing programs, and intensive public education campaigns. A specified reduction in quantity demanded can be expected upon implementation of a program which includes such measures. The model assumes that such a program is instituted whenever there is a shortage in available water supplies compared to current quantity demanded or in response to low carryover storage availability.

Curtailment of Interruptible Deliveries. The economic losses assigned to users of interruptible supplies are assumed to be limited to the cost of that supply in accordance with their usual water rate. Interruptible program deliveries are assumed to be cut back along with non-interruptible deliveries but at a higher rate relative to non-interruptible cutbacks.

Contingency Water Transfers. Water transfers are modeled using constraints as well as costs by source. These constraints include conveyance capacity, carriage water and other conveyance losses, and can be limited by the amount of water that can be transferred over a specified period or in consecutive years to emulate strategies for mitigating third-party impacts. If available, water costs by year type can be used.

Water transfers are also handled differently than other shortage contingency measures in the model. Using quadratic programming, a least-cost, economically efficient solution can be found for the sum of the economic losses to urban users and the total cost of the available supplies transferred. Alternatively, water can be transferred for shortage management using cost effectiveness. Water transfers for the purpose of alleviating depleted carryover storage conditions are always based on cost effectiveness.

Rationing. In LCPSIM, “rationing” is shorthand for a water allocation method designed to minimize the overall economic costs of a shortage by “balancing” the costs of forgone use among customer classes. Above a specified threshold level, commercial users are assumed to forgo use at a lower percentage rate compared to residential customers. Industrial customers are assumed to forgo use at an even lower percentage rate. Conversely, water use for the purpose of maintaining large landscaping is assumed to be curtailed at a greater percentage rate than residential use. The allocation method in LCPSIM is intended to mimic water agencies either setting the allocation of the remaining supplies by user type or maintaining provisions for exemptions due to serious adverse economic impacts (e.g., layoffs) for businesses.

Economic Losses. A single residential user loss function is used for all user types to generate shortage event losses. Users in the commercial and industrial water use sectors–are, above a specified threshold shortage size, when their marginal losses are assumed to be substantially higher–allocated proportionately less of the overall forgone use during shortage events by the LCPSIM logic. This mimics the shortage contingency management programs used by local water agencies. These programs can be a pre-established cutback schedule by user type and/or a case-by-case cutback exemption program which is sensitive to avoidance of business income and job losses.

Elasticity of Demand. In LCPSIM, the cost of additional supply reliability and the cost of shortages (including forgone use and the cost contingency supply and demand management measures) affect the level of the use of long-term conservation measures beyond those included in the base use values. This is because the economic optimization logic used in the LCPSIM depends on comparing the marginal cost of regional long-term conservation measures and the marginal cost of regional supply reliability and the marginal expected cost of shortages. Quantity demanded is therefore a function of the overall regional economic efficiency of water management. This is equivalent to the concept of price elasticity of demand but on an alternative marginal cost basis.

Demand Hardening. Long-term demand management measures that are adopted by water users can have a demand hardening effect. Although they can increase reliability by reducing the size, frequency and duration of shortage events, they can make these events relatively more costly when they do occur. A hardening factor can be set in the LCPSIM to simulate this effect (i.e., if conservation decreases demand by a specific percentage then the economic impact of forgone use of a specified size is computed as if the forgone use was greater, based on the hardening factor.)

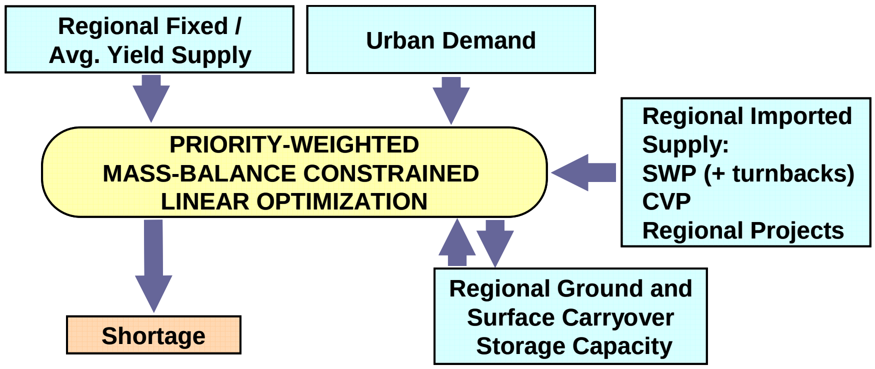
Unused SWP Supplies. The SWP and CVP water deliveries used by the LCPSIM are generated by the CALSIM project operations model. The CALSIM deliveries are driven by specified target delivery quantities which it tries to meet based on available inflows and storages on the SWP and CVP systems for each year of the hydrology used. Because these targets are set independently of the LCPSIM, an economically efficient water management plan can produce a level of reliance on regional supply and conservation measures which can result in the target deliveries for a region having been set too high for the wetter years. In these years, the capacity for deliveries to carryover storage can be exceeded, either because the volume to be stored exceeds the available space or the annual put rate is insufficient. This “excess” supply is assigned to the SWP because it is assumed by the LCPSIM to be the marginal supplier. This excess urban delivery quantity can be used to augment annual urban deliveries to other regions, to agricultural users, or used to reset the target deliveries in CALSIM II.

LCPSIM Simulation Logic

The following is a breakdown of the LCPSIM by its major logic elements.

Basic LCPSIM Water Management Simulation Elements. Figure 6 represents the basic water management operations simulation elements in the LCPSIM.

Figure 6. Basic LCPSIM Water Management Simulation Elements



Regional Fixed / Avg. Yield Supply: Water supplies include within-region surface and groundwater supplies exclusive of carryover operations expected to be available for the study year level (e.g., 2030). These supplies include recycling and groundwater recovery. Because of a lack of information about the year to year availability of the supplies from within-region reservoir storage and groundwater operations, they are included as long-term averages unless otherwise noted.

Regional Variable Supply Sequences: Variable supplies available to the region are included as annual quantities over the hydrologic period being represented (e.g., the 82 years represented by the period 1922 to 2003). LCPSIM uses three supply sequence files: SWP supply, federal service contract delivery supply, and regional variable supply. In the South Bay Area, the federal service contract delivery sequence represents CVP deliveries for the South Coast region, the sequence represents federal deliveries made through the Colorado River Aqueduct.

If available, the data used are produced by hydrologic modeling studies. State Water Project and Central Valley Project deliveries are developed by using CALSIM II, the Department's project operations model for the SWP and the CVP. Colorado River Aqueduct Deliveries were sent a long-term average based on the recent Quantification Settlement Agreement.

For the South San Francisco Bay Area, the regional variable supply sequence is developed from modeling done by the East Bay Municipal Utility District (Mokelumne Aqueduct) and the San Francisco Water Department (Hetch-Hetchy Aqueduct). For the South Coast Region, the regional variable supply sequence results from modeling done by the Los Angeles Department of Water and Power (Los Angeles Aqueduct). If a time series of regional groundwater availability (exclusive of conjunctive use operations) is available, the quantities can be added to this file.

A fourth supply file of "excess" SWP deliveries can also be used. If a portion of the SWP supply available to a region exceeds both current quantity demanded and available carryover storage capacity, a time series file of the excess quantities can be generated by LCPSIM for that region and used to augment SWP deliveries to another region.

Urban Demand Sequence: The demand sequence consists of two components, non-interruptible, and non-interruptible demand. The demand sequence for non-interruptible urban deliveries was developed from a forecasted quantity demanded for the study level (e.g., 2030) being investigated. For future studies, it is expected that this value will come from studies using the Institute for Water Resources Municipal and Industrial Needs model. For current studies, the forecasted level of quantity demanded is from DWR Bulletin 160-98. This quantity was then turned into a stochastic sequence for the hydrologic study period. This was accomplished using historical rainfall records starting in 1883.

A two year running average was extracted from this data and ranked by amount. The rankings were then related by equivalent rankings to a ranked demand sequence generated for the historical period of record by assuming a normally distributed variable about the forecasted quantity demanded and an assumed standard of deviation of 2.9 percent. The demand sequence associated with the LCPSIM study period (e.g., 1922 to 2003) was then used as model input. The source of the 2.9 percent value for the standard deviation of water use was a study done by the Metropolitan Water District of Southern California of retail water demand variation in their service area. As in the case of supply, the water demands used in the LCPSIM are applied values.

The interruptible component of demand for the South Coast Region was developed from information contained in the annual financial reports of the Metropolitan Water District of Southern California. This component was held constant for the study period and the quantity specified assumes that other sources of supply will not be used in-lieu. No interruptible delivery program was assumed for the South San Francisco Bay Area.

Regional Ground and Surface Carryover Storage Capacity: The carryover storage element of the basic water management simulation algorithm was developed from information published by agencies within the study regions as well as discussions with their staff. The information obtained was used to estimate the average amount of groundwater basin and reservoir storage capacity available for the purpose of storing currently available water for use in future years. This capacity is that amount over and above the capacity needed for regional intra-year operations. In the same manner, annual rate ceilings for deliveries to carryover storage (puts) and withdrawals from carryover storage (takes) were developed.

Carryover storage operations can involve storage capacity within the region or external to the region. Puts involving groundwater storage can be accomplished by injection wells, spreading basins, or in-lieu deliveries (water users normally pumping groundwater are switched to surface water supplies). Conversely, takes from groundwater storage either can be accomplished by groundwater pumping or by switching water users who normally take surface water to groundwater pumping, allowing the now unused surface supplies to be delivered elsewhere.

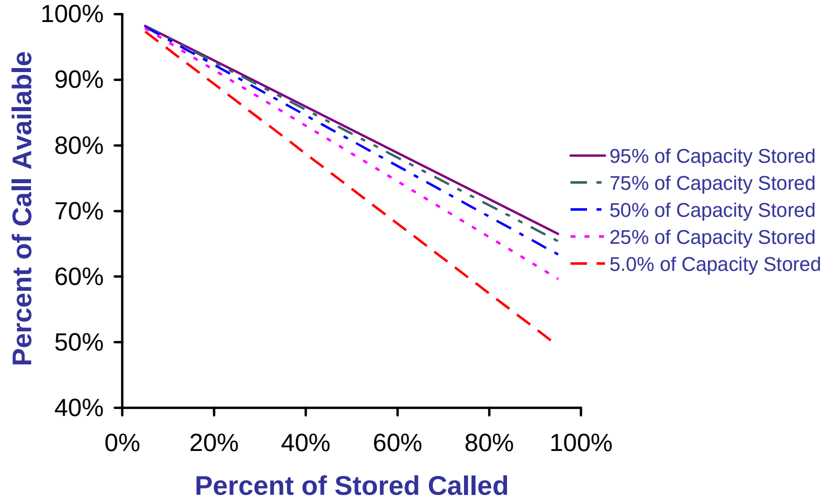
Information entered into LCPSIM for individual carryover storage operations includes the capacity which can be operated, the initial fill, the annual put capacity, the annual take capacity, the conveyance facilities which will be used for puts and takes, any losses associated with storage operations, the on-site unit cost of the put and take operations, and whether one or more storage operations operate the same physical storage space.

SWP project deliveries direct to San Joaquin Valley groundwater storage are also supported in LCPSIM. The stored water is then made available for delivery to the study region in subsequent years.

Additionally, LCPSIM can allow for water market transfers for the purpose of replenishing depleted carryover storage. A state of depletion is defined to exist if the total supply stored is less than the capacity to deliver that amount from carryover storage. A LCPSIM parameter setting determines the depletion threshold for this type of transfer to take place (e.g., carryover storage at 80% of the delivery capacity).

Takes from carryover storage are constrained in the LCPSIM to amounts accrued from puts in previous periods, with an allowance for a specified initial fill. Takes from carryover can also be constrained by a hedging function within the model. This hedging function can be assigned to any or all carryover operations but only on a total capacity basis. Figure 7 depicts the functional form used.

Figure 7. LCPSIM Hedging Function Example



From the example function shown, if the amount in storage is 50 percent of the total storage capacity of the operations selected to be hedged and 25 percent of the stored amount is needed to meet demand, 90 percent of the needed amount will be supplied. If 75 percent of the stored amount is needed, 70 percent of the needed amount will be made available. Three input parameters affect this function, the storage capacity ratio at which hedging is employed and two parameters which affect the absolute and relative slopes of the curves which relate quantity needed to quantity supplied.

Take constraints set in the carryover storage data file for reservoir storage can also be used to represent a specific hedging strategy. LCPSIM also accepts water bank take constraint rules based on either reducing the allowed take in consecutive-year take situations (e.g., Arvin-Edison WSD banking program) or on the project delivery received by the bank operator as a percentage of their contract full-delivery quantity (e.g., Semitropic WSD banking program)[1].

Priority-Weighted Mass-Balance Constrained Linear Optimization: This model element is used to balance water use with water supply, simulating regional water management operations. The put and take priorities for each storage operation are dynamically set by calculating the ratio of the stored supply to the take capacity for each storage operation for each annual time step. This ratio is then used to assign relative priorities for that time step: the lower the ratio, the lower the take priority and the higher the put priority. This strategy is designed to maximize supply availability from carryover storage when the desired deliveries to users exceed the supply available from other sources. Alternatively, these priorities can be set statically for each storage operation based on entries in the carryover storage data file. Statically based priorities, in general, assume that when carryover supplies are needed to meet desired deliveries, water is preferentially taken from surface storage carryover supplies as opposed to groundwater storage carryover supplies. When supplies are available for

[1] Arvin-Edison's MWDSC take limit is reduced for each consecutive year for which a take is made. Semitropic's MWDSC take limit is equal to the bank's pumpback capacity plus the product of MWDSC's percentage share of the bank and Semitropic's SWP Contract Table A delivery after subtracting Semitropic's reserved amount of that allocation: Pumpback Capacity + Share of Bank * ((Table A Allotment * Percentage of Table A Delivered) - Reserved Table A).

refilling carryover storage, the supplies are preferentially used for groundwater storage carryover operations as opposed to surface storage carryover operations. Dynamically set put priorities are always used for water market transfers made to replenish depleted carryover storage, however.

If the water supply from the sources other than carryover storage is greater than desired deliveries to users then this balance can be achieved by needed deliveries to carryover storage. Deliveries to carryover storage are constrained by annual put ceilings and available carryover storage capacity after adjusting for put efficiencies (if less than 100 percent). The amount of supply remaining subsequent to this balance due to these carryover storage delivery constraints is used to estimate how planned SWP operations might be reduced in specific years compared to the target deliveries sent in CALSIM II.

If the supply from the sources other than carryover storage is less than desired deliveries to users, this balance can be achieved by deliveries from carryover storage or by reducing use or both. Deliveries from carryover storage are constrained by the annual take ceilings and the amount of stored water available. Desired deliveries are separated into three categories: base use deliveries, deliveries for contingency conservation affected use, and interruptible use deliveries. Contingency conservation affected use is that amount of non-interruptible use which can be expected to be eliminated on a short-term basis in response to programs such as drought alerts and conservation advice in the media, local agency water-waster patrols and alternate-day watering rules, etc.

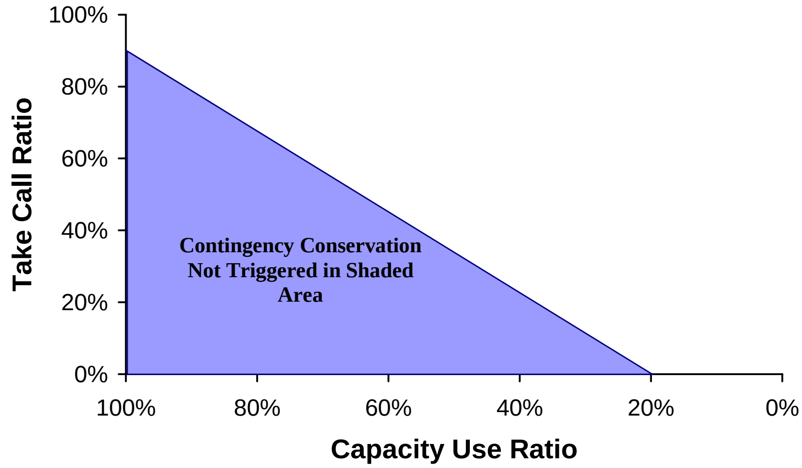
Although a mass balance constraint is used to assure that supplies equal uses (aside from any supplies excess to the quantity demanded that can’t be delivered to carryover storage), how this balance is achieved is set by assigning priority weights to affect how the water is moved. The algorithm maximizes quantities weighted by priorities subject to the imposed system constraints.

To assure that failing to meet the quantity demanded for current base consumptive use is a “last resort”, meeting it has a very high priority. Contingency conservation affected current consumptive use has a somewhat lower priority. Interruptible use has a relatively low priority compared to the other use categories. Even lower priorities are assigned to deliveries to carryover storage. Because of how it is used, however, a relatively high priority is given to reserve reservoir storage to insure it is refilled as quickly as possible, even if contingency conservation is still in effect.

On the supply side, water delivered from sources other than carryover storage is assigned the lowest priority (i.e., the model uses this source first). Next in priority are deliveries from carryover storage, with the weight scheme giving preference to deliveries from reservoir carryover.

Overriding the allocations based on weights are contingency constraints which are implemented to reflect contingency shortage management programs. One such contingency constraint is a function relating interruptible program cutbacks to the level of the supply made available for delivery to the non-interruptible uses. An input parameter in the model determines the level of reduction in deliveries to the non-interruptible uses at which point the interruptible program is zeroed out.

Figure 8. Trigger Function for Contingency Conservation

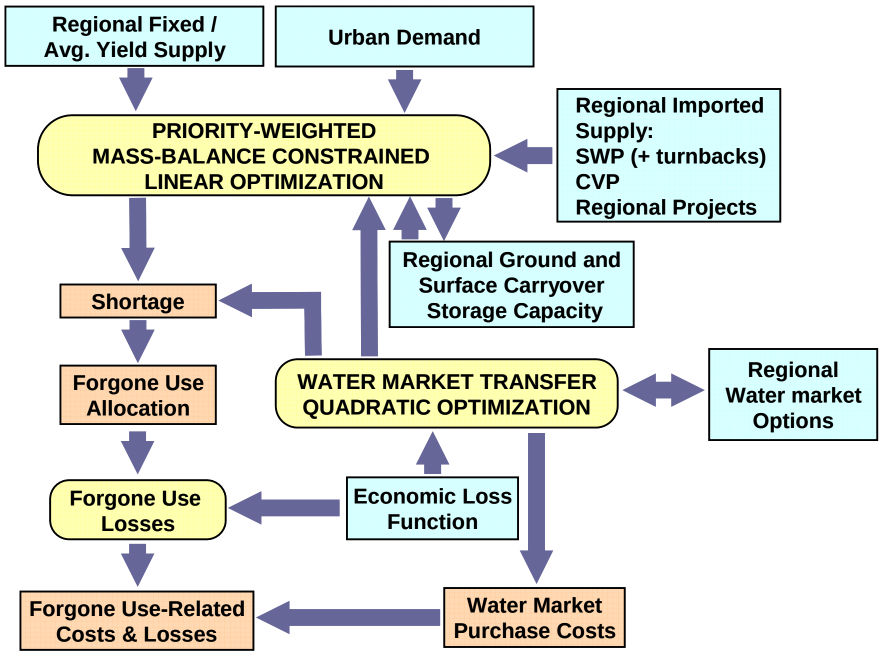


Another contingency constraint keeps carryover supplies from being delivered from reserve reservoir storage facilities. This category of storage is available for use only if supplies delivered from sources other than carryover are less than that needed for base and interruptible use plus the amount needed to refill any available reserve reservoir storage capacity. A contingency constraint is also used to curtail supplies allocated to contingency conservation affected use. This represents the institution of a contingency conservation program and allows supplies which would have been directed to this category of use to be allocated elsewhere. Shown in Figure 8 is the function used to implement this constraint. The take call ratio relates desired deliveries to supply availability, including the supply available from carryover storage but exclusive of water transfers that have a shortage threshold constraint imposed. The capacity use ratio relates the total amount of capacity available to store carryover supplies to the total amount of water in carryover storage. Both of these ratios are input parameters to LCPSIM.

Shortage: After the mass balance is performed, there may not be sufficient supplies available from current year supplies and withdrawals from carryover storage to meet the quantity demanded. Before determining the economic losses from forgone use, the ability of contingency water market transfers to augment current year supply is simulated.

Regional Water Market Transfers and Economic Losses. Shown in Figure 9 are the elements from Figure 8 with the addition of elements used to simulate water market transfers and an element used to determine economic losses from forgone use.

Figure 9. Regional Water Transfers and Economic Losses



Regional Water Market Transfer Options: Water market transfer options are input into LCPSIM in terms of the quantity available from a specified source, the cost obtaining the water at the source, what facilities will be used to convey the transferred water, any losses during conveyance (e.g., carriage water for transfers involving the Delta), and any constraints on the frequency of use of the transferred water from that source. Multiple sources can be used. Also, transfers which have a forgone use threshold constraint can be specified.

The cost of obtaining the transferred water can be entered as coefficients of a quadratic function, representing the situation where the unit price increases linearly as the amount purchased is increased. If available, the cost data can be entered as a file of cost coefficients by year type.

Identification of the conveyance facility is needed to determine what capacity remains for moving the water to be transferred and to determine the conveyance cost. If the conveyance facility is a federal service contract facility that is used to convey exchanged SWP Table A contract deliveries then the aqueduct capacity for transfers is increased during those years when Table A deliveries are cut back. For example, MWDSC delivers Colorado River water to Desert Water Agency and Coachella Valley Water District through the Colorado River Aqueduct in exchange for their SWP contact deliveries.

Frequency of use constraints can be used to represent the need to respect the potential for serious third-party impacts. These constraints are specified by source and are in the form of a limit on the maximum amount of water which may be transferred during consecutive years and in terms of the maximum quantity to be made available over a ten year period. Both of these constraints are expressed as a percentage of the maximum to be made available during any single year event. Another third-party impact mitigation mechanism is a constraint that can be placed on transfer sources that restrict their use to shortage events which exceed a specified percentage of regional use. These constraint parameters are overridden if time-series transfer quantity constraint files are available.

Simulated water market transfers include not only those made for shortage event management but also those made to augment carryover storage. The latter type of transfer can be triggered when carryover storage is depleted (i.e., when the amount of stored supply is less than the available take capacity). The trigger can be set in the LCPSIM parameter file as a percentage of take capacity.

System conveyance capacity constraints and delivery efficiency factors for water market transfers in the form of time series files can be used by LCPSIM. LCPSIM can use such files for transfers from the either Sacramento Valley, the San Joaquin Valley, or both.

Forgone Use Allocation: After accounting for water transfers, this model element is used to allocate forgone use resulting from the remaining shortage among the different user classes represented in the model: industrial users, commercial and governmental users, residential users, and large landscape users. This allocation is determined by input parameters for the non-residential users. These parameters represent the respective fractions of the residential percentage of use forgone that will be allocated to them. For example, a parameter value of twenty-five percent for industrial users means that these users will be held to a forgone use equal to twenty-five percent of the percentage use forgone by residential users. This results in the residential users forgoing use, in percentage terms, larger than the overall forgone use. This effect can be moderated by specifying that deliveries to large landscape irrigators will be curtailed at a greater percentage rate compared to residential users. An input parameter determines the level of overall forgone use at which this allocation takes effect. This is intended to represent strategies used by water agencies to protect businesses and institutions from serious economic damage and job loss during shortage events. Some water agencies have explicit water allocation rules. Other agencies have hardship exemption programs that have a similar result.

Economic Loss Function: This model element assigns economic losses to forgone use. The loss function is input into LCPSIM either as coefficients of a polynomial function which relates a percentage forgone use to a total cost of that forgone use or as the coefficients of a constant price elasticity of demand function.

The LCPSIM has the ability to use a polynomial loss function because this functional form has the advantage of allowing “threshold effects” to be modeled. There is evidence from contingent valuation studies (SWRCB Bay-Delta Hearings, Exhibit 51 and others) that it is possible that the inconvenience of dealing with water agency policies during shortage events (e.g., alternate day watering and gutter flooder regulations, water waster patrols, etc.) is perceived as a hardship over and above the value associated with the amount of water no longer available for use. This phenomenon, if real, can be represented by a loss function in which, over a limited range, associates a higher marginal value of supply at lower forgone use levels than at higher shortage levels.

The ability to use a constant price elasticity of demand function is also provided as an alternative, more conventional, means of representing demand (i.e., there is no “threshold effect”). It has the advantage of using just two parameters that are readily available from most econometric studies of water demand. This specification of the loss function results in the acceptance of an appreciably greater number of small shortage events at the least-cost LCPSIM solution compared to the polynomial function. Tables 1 and 2 show a comparison between results produced by the two functional forms.

For comparison, the elasticity value of -0.10 used for the CPED function was set to replicate the forgone use losses at 25 percent as determined by the polynomial function. (A 1996 elasticity study done for DWR Bulletin 160-98 found an average elasticity of -0.16 for urban residential users.)

Table 1. Example Polynomial Loss Function Values

	Willingness to Pay to Avoid Event		
	Acre-Foot Use/Year/Household		
Forgone Use	0.75	0.65	0.55
0%	$0	$0	$0
5%	$49	$43	$36
10%	$145	$126	$106
15%	$278	$241	$204
20%	$439	$380	$322
25%	$618	$535	$453
30%	$804	$697	$590
35%	$990	$858	$726

Table 2. Example CPED Loss Function Values

	Willingness to Pay to Avoid Event		
	Acre-Foot Use/Year/Household		
Forgone Use	0.75	0.65	0.55
0%	$0	$0	$0
5%	$29	$25	$22
10%	$79	$69	$58
15%	$166	$144	$122
20%	$323	$280	$237
25%	$618	$535	$453
30%	$1,194	$1,034	$875
35%	$2,376	$2,059	$1,742

When they occur, the calculated losses can be increased by a specified percentage amount to reflect the more severe consequences of consecutive shortage events of a size greater than another specified percentage amount. Both percentages are model input parameters. This effect falls off as a power function of the number of years between events and does not apply if the next loss event follows by more than two years.

The losses are also adjusted by the amount of demand hardening present in the system compared to the base. Hardening is computed from the ratio of the quantity of use reduction due to conservation to total quantity of use prior to that reduction and expressed as a percentage. This percentage is then multiplied by a percentage specified as a LCPSIM input parameter (the demand hardening adjustment factor) to get a forgone use adjustment factor.

This latter value is used to adjust the quantity of forgone use before the loss function is applied. For example, if pre-adjustment forgone use is ten percent, the demand hardening percentage is twenty percent, and the demand hardening adjustment factor is fifty percent, then forgone use is increased to eleven percent for the purposes of determining economic losses.

The unit value of the losses incurred by interruptible supply customers is the same as the unit price paid for that supply. This is based on the assumption that the price reflects the value of that supply discounted for unreliability by knowledgeable users of that source of supply.

Market Transfer Quadratic Optimization: If the mass balance algorithm results in insufficient supplies to meet desired deliveries, this model element is used to determine the total amount of water to be transferred to help meet the insufficiency. Unit water purchase costs from each source are adjusted upward by their respective conveyance losses and augmented by their respective conveyance costs. The unit purchase costs from any source can be specified as coefficients of a quadratic function, representing a unit cost that increases linearly as the amount used is increased. Quantities available from each source are constrained by the applicable conveyance capacities. The quadratic programming solution which minimizes the sum of the forgone use-related costs and losses and the costs of transfers is used to determine the quantity transferred to reduce foregone use.

Expected Costs and Losses Curve. Shown in Figure 10 are the elements from Figure 9 with the addition of iteration logic. The summation of water transfer costs and forgone use costs and losses produces forgone use-related costs and losses for an individual year. Iterating through the years in the hydrologic record produces expected costs and losses based on the level of adoption of regional long-term reliability augmentation options. Further iterating these expected values by incrementally increasing the level of adoption of regional long-term reliability augmentation options generates a downward sloping curve of expected costs and losses points as shown in Figure 11. Conveyance, potable and wastewater treatment, delivery, and carryover storage operations costs are included.

Figure 10. Expected Costs and Losses Curve Logic

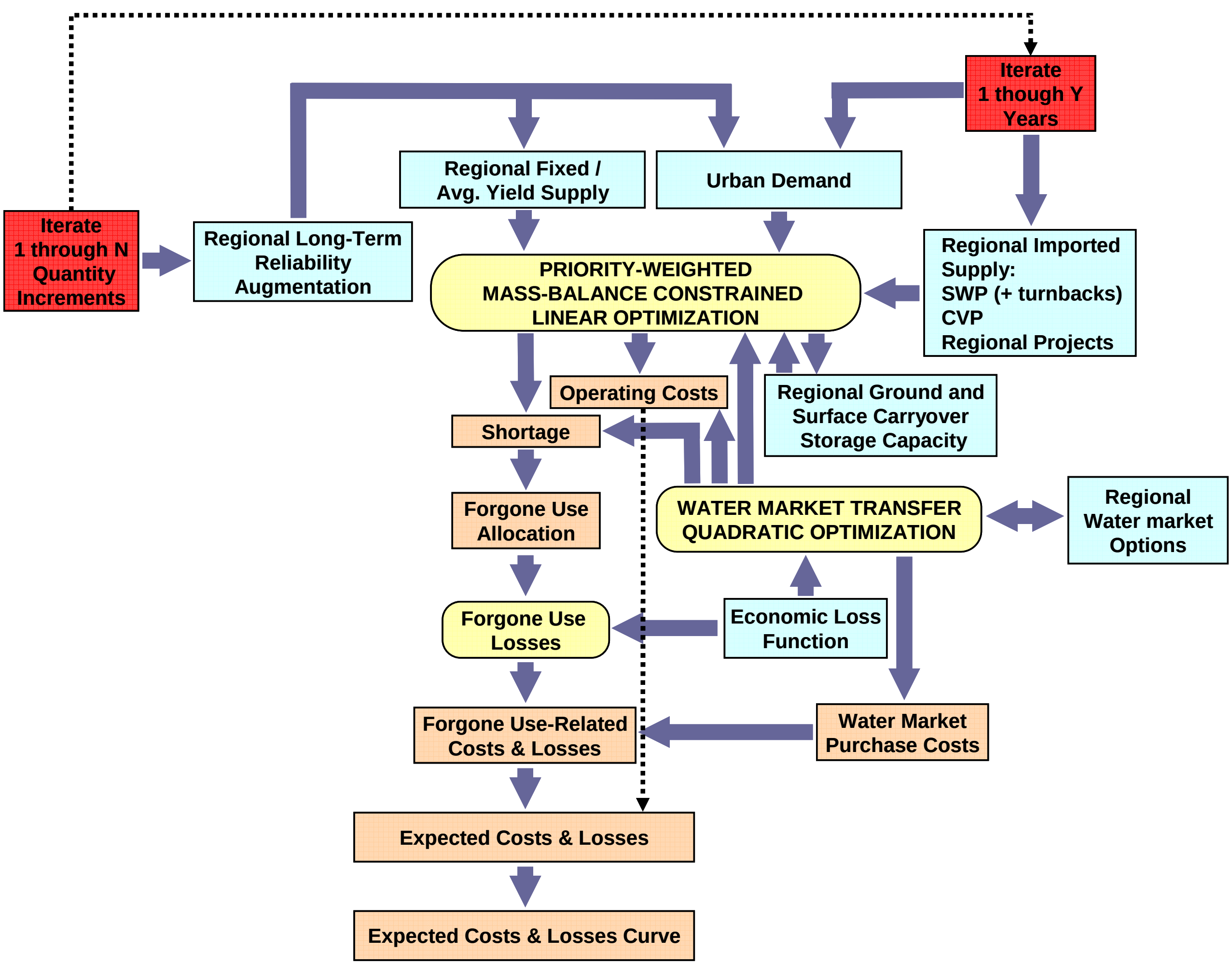
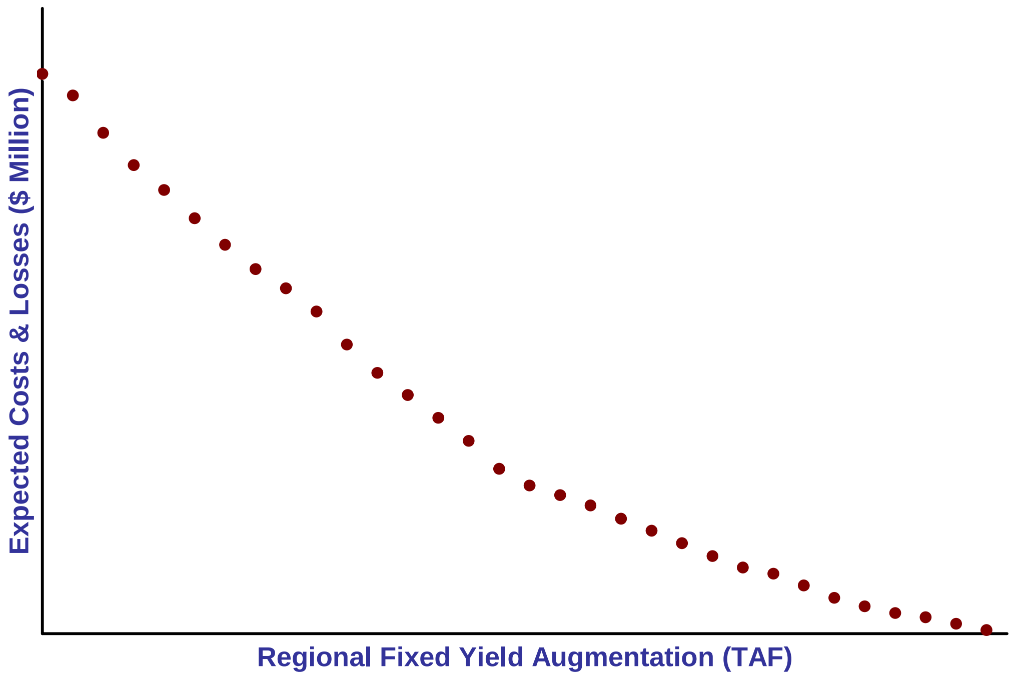
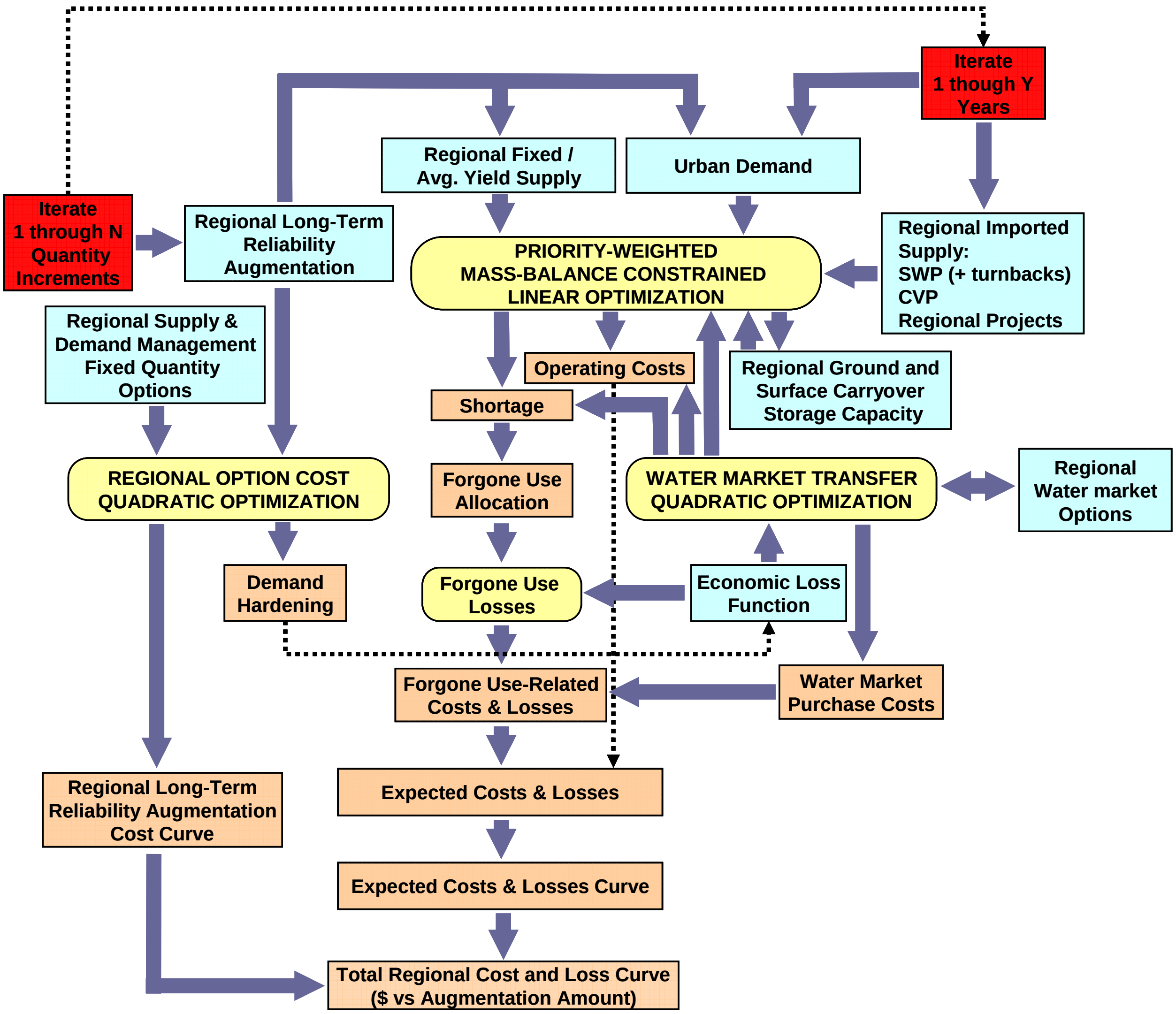


Figure 11. Expected Costs and Losses Curve



Total Regional Cost and Loss Curve. Shown in Figure 12 are the elements from Figure 10 with the addition of elements which can be used to either augment regional fixed yield supply or reduce regional demand, depending upon the type regional reliability management option used. This logic produces and upward sloping curve of reliability augmentation cost points. The costs of reliability augmentation are summed with the expected forgone use-related costs and losses to produce a saddle-shaped curve of total cost and loss points as shown in Figure 13.

Figure 12. Total Regional Cost and Loss Curve Logic



Regional Long-Term Reliability Augmentation: This element adds an increment of a specified constant size of regional option use which either augments the regional supply by a fixed annual yield or reduces demand by a fixed annual quantity or does some combination of both.

Regional Supply and Demand Management Fixed Quantity Options: Information on individual regional water management options used by LCPSIM includes: the amount available from that that option, the unit annualized capital and O&M cost of that option, and the type of option. The type of option is used to determine either the cost of regional potable water and wastewater treatment and distribution, or, in the case of conservation, that these costs don't apply. To determine the effect of conservation on wastewater treatment costs, interior and exterior conservation options are identified separately.

Because reuse of surface return flows and deep percolation can help meet applied water demand quantities, the parameter file includes percentage values for the effectiveness of interior and exterior applied water conservation, respectively. These percentages are used to account for the effect of reuse on the ability of conservation to reduce need for imported and within regional supplies and on the cost of achieving that reduction.

The unit cost of any option can be specified as coefficients of a quadratic function, representing a unit price that increases linearly as the amount used is increased. The costs are from the perspective of statewide economic efficiency, and are lifecycle costs whenever possible. Conservation options, for example, are adjusted to reflect any energy costs savings which might accrue to the user.

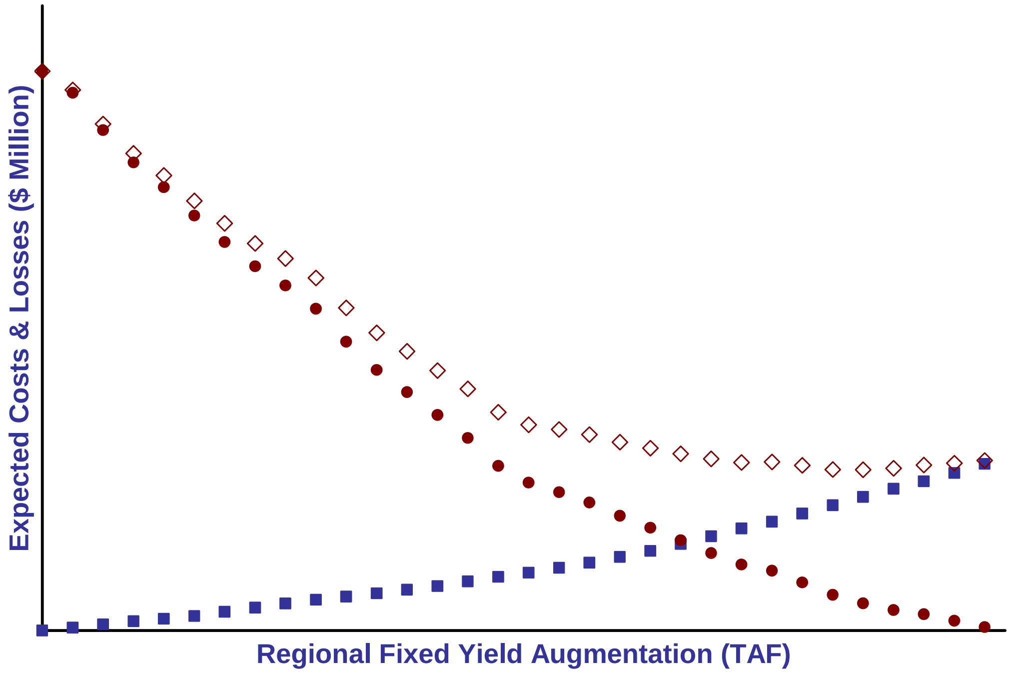
Regional Option Cost Quadratic Optimization: This model element is used by LCPSIM to relate the amount of option use to the total cost of that amount of option use. For a particular level of option use, the options are assumed to be implemented in manner that minimizes the cost of achieving that level of use when both annualized capital and O&M costs and regional potable water and wastewater treatment and distribution costs are considered. Because quadratic option costs can be entered, a particular level of use may be achieved by implementing less than the total amount specified as being available from any one option.

Demand Hardening: The amount of conservation included by the optimization routine is tracked and this information is used in the economic loss function element to adjust economic losses for demand hardening.

Incremental Regional Systems Operations Costs: The economic costs and losses related to forgone use for the changes in regional systems operations costs realized as a consequence of implementing the use of the local supply augmentation and demand reduction options are adjusted for changes in regional water management operations costs. These costs include SWP conveyance costs to the region, conveyance costs on other affected aqueducts supplying the region, and regional potable water and wastewater treatment and distribution costs. The conveyance costs include the cost of wheeling transferred water.

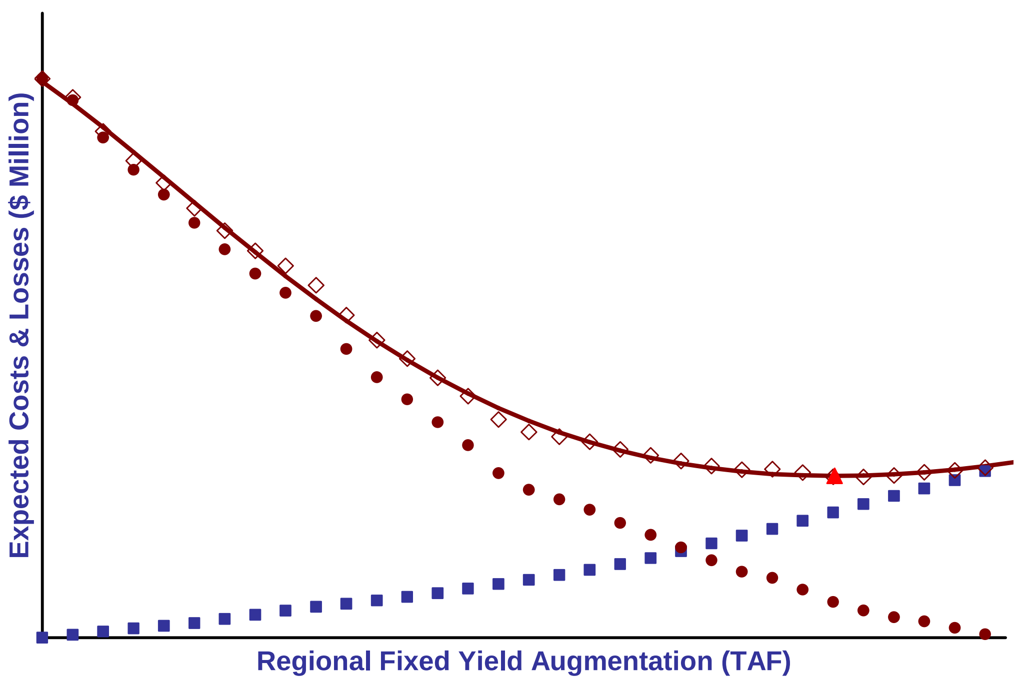
Unit costs of aqueduct conveyance, regional potable water and wastewater treatment and distribution costs are entered as LCPSIM parameters. Also entered are per-capita costs to regional water agencies to manage and rationing programs along with the forgone use threshold at which it assumed a rationing program will be instituted. The contingency conservation program cost is imposed whenever the water management simulation logic in LCPSIM cuts deliveries to the contingency conservation affected use category. The cost of managing a water use reduction exemption program is an example of a cost that would be incurred in a rationing program.

Figure 13. Total Regional Cost and Loss Curve



Solving for the Least-Cost Use of Regional Water Management Options. Figure 14 shows the result of applying a polynomial smoothing function to the total regional cost and loss curve points and then solving for the least-cost point (triangle):

Figure 14. Least-Cost Solution Point



The model also has the capability of solving for the point that meets specified hydrologic reliability criteria. This capability is useful for comparing the economic efficiency cost of (if any) of planning on the basis of hydrologic reliability criteria instead of economic efficiency. The reliability criteria are entered in LCPSIM by specifying one or more forgone use percentages and providing not-to-exceed frequencies for each forgone use percentage specified.

Results Available for Viewing and Saving: Both incremental and summary results are available in tabular form:

- LCPSIM input data by year and water year type average
  - Supply by source
  - Quantity demanded

- Detailed data by regional water management option use increment and by year
  - Supply
  - Carryover storage by location
  - Contingency conservation
  - Base and interruptible program use
  - Transfers by source
  - Percent forgone use
  - Forgone costs and losses
  - Percent of available transfer supply transferred by source

- Summary data by regional water management option use increment
  - Option use cost
  - Costs and losses from forgone use and water transfer purchase costs
  - Regional system operations costs by cost component
  - Number of shortage events
  - Average sufficiency (1 – average forgone use)
  - Total costs
  - Fitted total costs (fitted polynomial smoothing function)
  - Residual (total minus fitted total costs)
  - Marginal costs from fitted function
  - Quantity and frequency of transfers by source

- Summary data for least-cost solution
  - When comparing alternative to base
    - Change in total costs and losses
    - Incremental SWP/CVP supply available for use or carryover storage
      - Hydrologic period average
      - Dry year average
    - Incremental unused SWP/CVP supply
      - Hydrologic period average
      - Dry year average
  - Total costs and losses
  - Forgone use costs and losses
  - Fixed options cost
  - Fixed option use
  - Carryover option use
  - Carryover option use
  - Regional Operations cost
  - Forgone use during 90/91drought period
  - Total and average cost of transfers
  - Supply transferred from all sources by source

- Cost of transfers by source
- Transfer value

Data for the least-cost solution by year

- Supply
- Carryover storage by location
- Regional carryover storage use
- Contingency conservation
- Base and interruptible program use
- Water available from all sources for transfer
- Supply transferred from all sources
- Cost of transfers
- Forgone use quantity
- Percent shortage
- Forgone use losses
- Unused SWP supply
- Regional system operations costs

Data for the least-cost solution by water year type average

- Supply
- Regional carryover storage use
- Transferred supply
- Incremental SWP delivery
- Incremental CVP delivery
- Forgone use
- Forgone use losses
- Cost of transfers

Data for the least-cost solution for the use of regional water management options is also available in graphical form (this data is also available for the hydrologic reliability solution criteria):

Determination of least-cost point for regional water management option use

- Sequence of net costs and losses from forgone use and water transfer purchase costs
- Sequence of regional water management option costs
- Sequence of total costs
    - Fitted polynomial smoothing function curve
    - Least cost point
    - Point at which hydrologic reliability criteria are met

Hydrologic reliability exceedence curve

Trace of yearly regional water management operations

- Supply
- Unused SWP supply
- Carryover operations
- Transfers
- Contingency conservation
- Forgone base and interruptible program use

LCPSIM Elements for Carryover Storage Augmentation Option. LCPSIM offers a limited ability to augment carryover storage capacity as an option. Only one existing carryover storage operation can be selected to be augmented. The augmentation assumes that annual put and take capacities are increased in proportion to the size of the augmentation. Information on which carryover storage operation is to be augmented and the cost of adding storage capacity to that operation is entered along with the data entered for the other regional management options. Shown in Figure 15 is the overall least-cost solution for the analysis of augmenting regional carryover storage capacity (triangle). Figure 16 depicts the LCPSIM logic used for the analysis of carryover storage capacity augmentation. Additional data applicable to the analysis of carryover storage capacity augmentation are available as results.

Figure 15. Overall Least-Cost Solution for Carryover Storage Augmentation

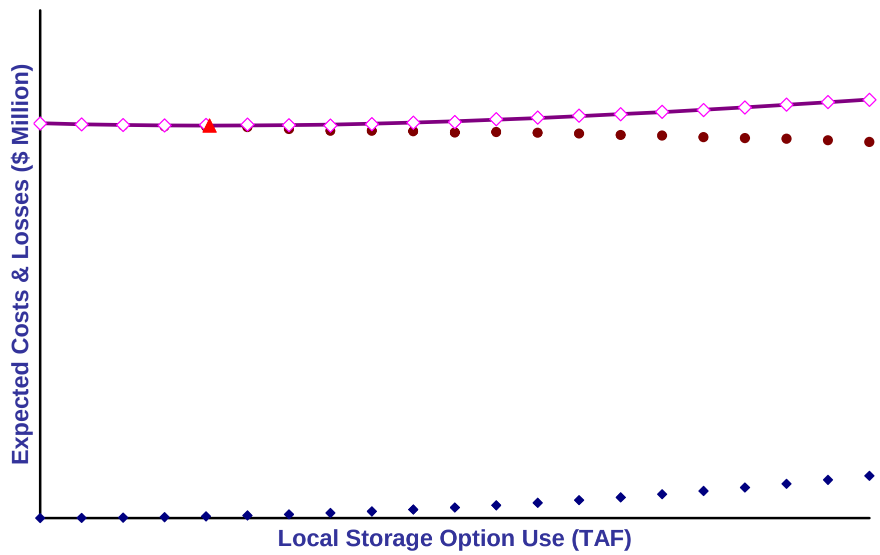
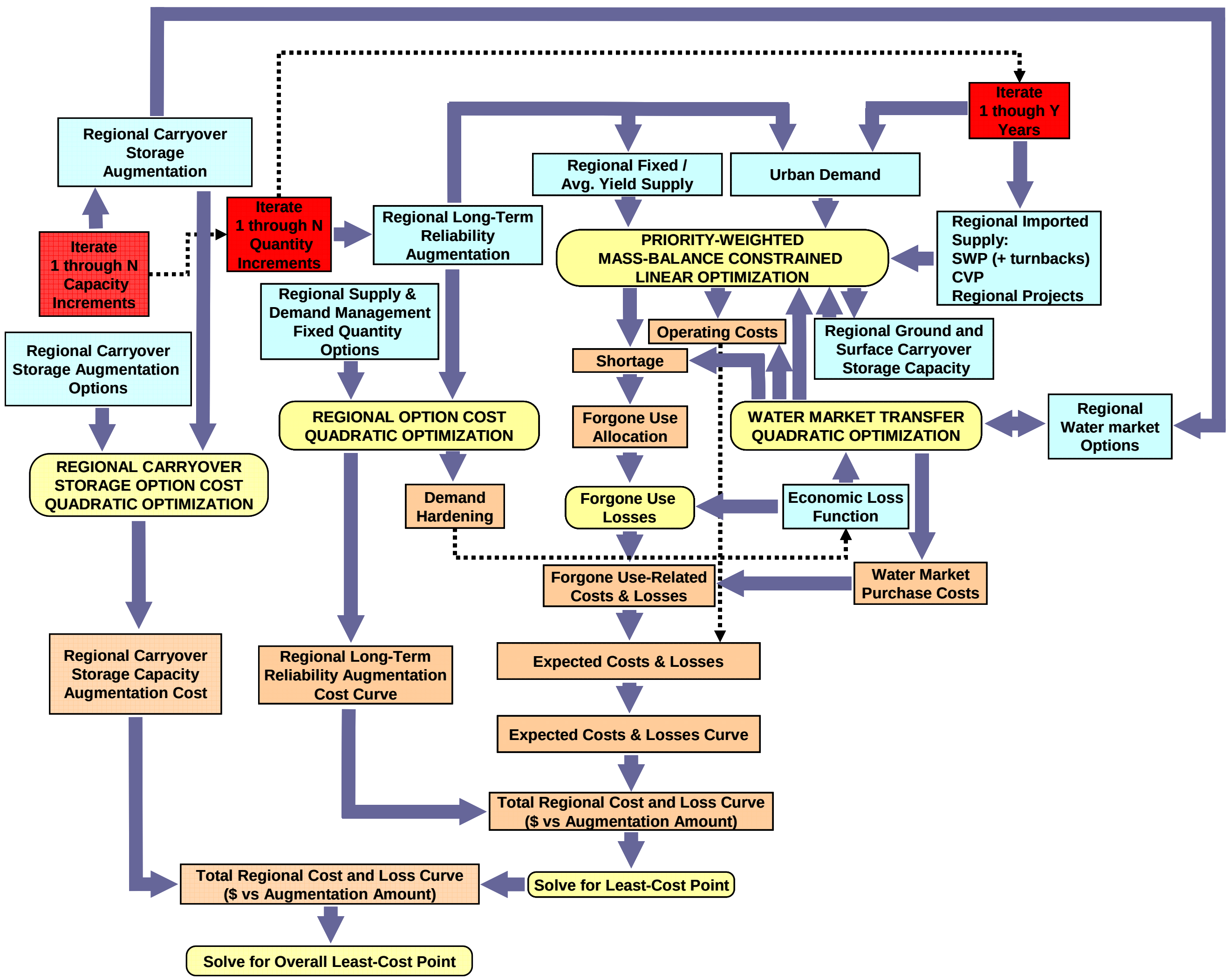


Figure 16. Analysis of Carryover Storage Augmentation



Regional Option Cost Minimization Analysis with LCPSIM

LCPSIM can also be used to determine if the use of regional options alone can provide at least the same hydrologic reliability or shortage event-related cost and loss reduction benefits as a base scenario. For this type of analysis, the solution is least-cost only in the sense that the cost of regional option use is minimized. For the hydrologic reliability criterion, regional options are added to the alternative scenario to the point where the hydrologic exceedence curve of the base scenario is dominated (i.e., no point on the alternative curve falls below the base curve). For the economic reliability criterion, the same dominance strategy is used for an economic cost/loss reliability curve. For the expected value criterion, regional options are added to the alternative scenario to the point where the expected value of shortage event-related costs and losses is equal to or lower than in the base scenario.

LCPSIM Limitations

The LCPSIM is not appropriate for individual water agency management decisions because of the simplifying assumptions it makes about system operations. These assumptions were made in order to keep the input data requirements and the complexity of the model logic at a level commensurate with the requirements of the regional level of the DWR studies for which it was designed.

Economic benefits are in LCPSIM computed at specifically identified demand levels (e.g., Year 2020 level.) The model thereby conforms to CALSIM hydrologic output which is generated for specific study year levels and is tied to target deliveries and upstream depletions tied to those levels, rather than over a period of time. Because the economic life of the alternatives to be evaluated can be up to fifty years or more, benefit estimation will be biased if only a single study year level is used and if, for the study period, the LCPSIM results are not reasonably equivalent to the annualized sum of the discounted benefits prior to the year level used added to the discounted benefits subsequent to the year level used. Running the LCPSIM for multiple year levels over the study period will reduce the magnitude of this bias but require large amounts of data.

The LCPSIM uses regional operations studies for local imported supplies to obtain annual delivery information. Regional water supply sources that are not modeled on a year-to-year basis in the LCPSIM are assumed to be continually at their average year values. This simplifying assumption can bias the results by not capturing the costs and losses which can arise when deliveries from these regional supplies and the explicitly modeled imported supply systems are reduced concurrently and by not capturing the benefits of augmenting carryover storage when deliveries both sources are at their highest levels concurrently.

The determination of reliability benefits is done in the LCPSIM on the basis of a risk-neutral view of risk management. Risk-averse management (risk minimization) by regional agencies–which has been the predominant mode–would result in the justification of more costly water management measures than under the risk-neutral assumption. Also, the LCPSIM will not be as useful for water managers who base reliability investment decisions on the hydrologic (e.g., percentage of target delivery met) rather than economic performance of their system over a specified drought sequence (e.g., 1928 to 1934.) The loss function used could, however, be modified to more or less replicate this strategy.

LCPSIM assumes that the regions being evaluated have the facilities and institutional agreements in place to move water as needed to minimize the impact of shortage events. For this reason, the use of LCPSIM on a regional basis is only appropriate for regions where this assumption is likely to be generally true within the time frame being modeled: the South San Francisco Bay Area and South Coast Region.

If, in general, interconnections and joint management do not realistically characterize a region, the calculation of the benefits of additional reliability may be biased. For example, if the ability of the region to mitigate the costs of forgone use with regional water allocation programs is significantly less than assumed in LCPSIM, a higher value may be assigned to useable deliveries from a reservoir supply alternative in a particular subregion but the amount of the supply actually useable may be reduced (e.g., the reservoir may be relegated to more of a peaking supply because the greater use of constant "yield" conservation and recycling measures may be justified for that subregion, reducing the usability of reservoir deliveries in wetter years.) In any case, to extent that region-wide shortage contingency water allocation plans are expected to be put in place in the future, this bias will be reduced.

LCPSIM is designed to use base urban quantity demanded as estimated by the IWR-MAIN or similar model. The quantity demanded reflects the expected adoption of conservation measures, including those specified in Urban Best Management Practices MOU, and incorporates water price elasticity effects on use. These base urban quantity demanded amounts are not reduced further in LCPSIM in response to the higher urban user water prices which can be anticipated as regions use water pricing as a means of recovering the cost of increasing reliability. In accordance with the economic efficiency objective, quantity demanded is reduced in LCPSIM based on the marginal cost of alternatives to that reduction, however. If the water pricing strategy adopted by local agencies to recover costs reduces quantity demanded differently than the reduction logic in LCPSIM predicts, the model results will be biased.

The total cost/loss points generated by the LCPSIM simulation as the model responds to added increments of regional water management option use are intended to plot out a cost/loss response path. This point path is mathematically converted to a continuous function by using polynomial smoothing. This function is then solved analytically to identify the least-cost solution consisting of a level of use of regional water management options and the total costs and losses associated with that level of use.

LCPSIM is set up to be a "best estimate" model. It is not intended to provide confidence intervals for statistical hypothesis purposes.

As well as relying on a simplified representation of the physical configuration of regional water management system, LCPSIM is based on determining a "least-cost" solution from the perspective of statewide economic efficiency for the purpose of identifying the level of statewide interest in the commitment of resources to a proposed project or program. Local planning decisions are likely to be influenced by local cost effectiveness and political concerns as well as additional factors of importance to regional water agency managers and water users that are not necessarily related to the LCPSIM objective.

> The order of the polynomial smoothing function can be set by the model user based on the user's view of the trade-off between minimizing the rate of change in the slope of the function (i.e., a smoother function) and a function which is less smooth but more closely follows the path of the points (i.e., maximizes the goodness of fit). If the LCPSIM user feels that, on average, the real world operations would be unlikely to duplicate the results of the threshold-based operating criteria incorporated in the model, then fitting the model-generated points too closely would be likely to bias the model results.
>
> Selecting the starting and ending regional option use points for the simulation can also affect the results of smoothing. Adjusting the range of option availability is another trade-off that the user may make to exclude or include information that may or may not be useful for identifying an optimal solution point based on the user's judgment.
>
> If Excel® is installed, selecting **View Operations Trace** in the LCPSIM **Run/View Menu** will also make available a spreadsheet smoothing analysis utility which can be used to select the order of the polynomial smoothing function and the range of option use results to smooth which the analyst feels best represents the model output. These parameters can then be used to rerun LCPSIM to generate new results files.

Because LCPSIM is used to optimize regional economic efficiency from a statewide perspective, shortage event-related cost and loss values, operations cost values, as well as the short-term and long-term management option cost values are lifecycle costs whenever possible. For example, conservation costs are adjusted for end user energy savings and water supply costs include the cost of wastewater treatment. For this reason, LCPSIM results may not reflect decisions made by water agencies based on their perspective on costs. Also, water users may or may not use information on energy savings when they make decisions on adopting conservation measures.

Based on the context in which the results will be used, LCPSIM results should be compared to local agency water management plans to help determine whether it would appropriate – or feasible – to modify model to be more representative of the region from the local management perspective.

References

MWDSC Climate Effects Spreadsheet, personal communication with Brandon Goshi, Metropolitan Water District of Southern California, December 2004

Randall, D., Cleland, L., Kuehne, C. S., Link, G. W., and Sheer, D. P. “Water Supply Planning Simulation Model Using Mixed-Integer Linear Programming ‘Engine.’” Journal of Water Resources Planning and Management, March/April 1997.

SWRCB Bay-Delta Hearings, State Water Contractors Exhibit 51, “Economic Value of Reliable Water Supplies”, dated June 1987.

Department of Water Resources, Bulletin 160-98, “The California Water Plan Update”, November 1998.

Appendix A

LCPSIM Input and Output Data

The information displayed in these example input data files is for the South Coast Region for a 2030 level of analysis. These numbers are for illustrative purposes only. The format of the files is ASCII and the data is stored without including the row headings.

Table A-1. Example Parameter File (*.prm)

Parameter	Value	Notes
1. Total conveyance capacity avail for Central Valley imports (TAF)	3,000	
2. Adjusted base average non-time series M&I water supply (TAF)	1,302	
3. Avg year applied M&I water use after base conservation (TAF)	4,886	
4. Standard deviation for M&I water use (%)	2.9%	
5. Number of years in precip ranking sequence	120	
6. Base long-term M&I conservation of applied water (TAF)	510	
7. Interruptable program applied use (TAF)	16	
8. Reuse of M&I applied water (TAF)	440	
9. Interior Conservation Effectiveness (%)	97.1%	
10. Exterior Conservation Effectiveness (%)	65.7%	
11. Federal service contract aqueduct capacity (TAF)	1,200	
12. Table A amount affecting Federal svc aqueduct capacity (TAF)	61	
13. Cost of federal svc aqueduct conveyance ($/AF)	$70.00	
14. Cost of federal svc aqueduct use to GW bank	$48.00	
15. Cost of SWP aqueduct use to region ($/AF)	$150.00	
16. Cost of SWP aqueduct use to GW bank ($/AF)	$22.00	
17. Value of interruptible program delivery ($/AF)	$241.00	
18. Fraction of interruptable supply treated (%)	46.0%	
19. Fraction of residential use that is interior (%)	62.6%	
20. Fraction of commercial use that is interior (%)	75.0%	
21. Fraction of industrial use that is interior (%)	82.5%	
22. Fraction of waste water centrally treated (%)	97.0%	
23. Cost of M&I potable water treatment and delivery ($/AF)	$114.00	
24. Cost of M&I waste water treatment ($/AF)	$47.00	
25. Cost of M&I delivery ($/AF)	$23.00	
26. Industrial customer size (% of total use)	5.7%	1
27. Commercial customer size (% of total use)	24.4%	2
28. Landscape customer size (% of total use)	5.0%	3
29. Cost/person for publicity campaign ($)	$0.25	
30. Use reduction with contngcy conservation campaign (%)	5.0%	
31. Take call ratio for using contingency conservation (%)	100.0%	4
32. Capacity use ratio for using contingency conservation (%)	20.0%	5
33. Industrial customer cut ratio (%)	25.0%	
34. Commercial customer cut ratio (%)	50.0%	
35. Landscape customer cut ratio (%)	200.0%	
36. Threshold for shortage allocation (%)	95.0%	6
37. Threshold to adj loss for proximate shortages (%)	0.0%	
38. Loss value adjustment factor for consecutive shortages (%)	0.0%	
39. Inverse power function exponent for loss value adjustment	1.0	7
40. Zero point for contingency reduction of interruptible deliv (%)	35.0%	8

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Table A-1. Example Parameter File (Cont.)

41. Shortage contingency water transfer threshold (%)	100.0%	9
42. Depleted carryover storage water transfer threshold (%)	80.0%	10
43. Cost/person for rationing program ($)	$0.50	
44. Rationing program threshold (%)	80.0%	
45. Regional urban population (thousands)	23,827	
46. Price for CPED function ($)	$1,074.00	
47. Elasticity for CPED function	-0.064	
48. Demand hardening adjustment factor (%)	50.0%	11
49. Hedging point	60.0%	12
50. Hedging call/storage factor	0.25	
51. Hedging storage/capacity factor	0.25	
52. Reserve reservoir storage hedging: 0: None, 1: Hedged	0	13
53. Regional reservoir hedging: 0: None, 1: Hedged	0	
54. Regional GW hedging: 0: None, 1: Hedged	0	
55. Regional GW bank hedging: 0: None, 1: Hedged	0	
56. SWP aqueduct GW bank hedging: 0: None, 1: Hedged	0	
57. Federal svc aqueduct GW bank hedging: 0: None, 1: Hedged	0	
58. Reserve storage management: 0: None, 1: Managed	0	14

Notes:

[1]Proportion of user category for which use reduction will be held to the industrial customer cut ratio compared to residential users

[2]Proportion of user category for which use reduction will be held to the commercial customer cut ratio compared to residential users

[3]Proportion of user category for which use reduction will be held to the landscape customer cut ratio compared to residential users

[4]Limit on the ratio of net current use to be met (including flexable storage refill, if any) to stored water available for current year use

[5]Limit on the fraction of carryover storage capacity filled before triggering contingency conservation

Subnote: 3 & 4 are used for triggering contingency conservation over and above a mass balance requirement for its use. When

[6]Below this point, all users will experience the same percentage reduction

[7]Proximate losses are increased by a loss adjustment factor to account for residual damage effects:

[8]At this point and above, interruptible deliveres are not made

[9]Used if a regional shortage has to exceed a specified percentage before transfers from this source type are allowed

[10]The ratio of supply in carryover storage to total carryover storage take capacity at which transfers are triggered

[11]The factor by which use reductions through conservation options as a percentage of initial use are used to adjust shortage size

[12]Parameters used for hedging logic: if storage is less than hedging point then percent of storage made available is

[13]Storage categories included for hedging purposes (hedging is applied to the total storage amount)

[14]When managed is selected, top priority is given to refill for this type of storage, triggering conservation if required

Table A-2. Example Regional Water Management Options File (*.opt)

Source[1]	Amount Avail (TAF)	Cost (Base) ($/AF)	Cost (Incremental) ($/TAF)	Source[2] (Type)	Description (AlphaNumeric)
1	150.0	$249	$2.50	2	Indoor Conservation Level I
2	5.0	$1,070	$87.20	2	Indoor Conservation Level II
3	112.0	$68	$1.40	3	Outdoor Conservation Level I
4	71.0	$1,305	$0.00	3	Outdoor Conservation Level II
5	171.0	$360	$2.00	1	Water Recycling Level I
6	212.0	$841	$1.70	1	Water Recycling Level II
7	208.0	$1,306	$1.10	1	Ocean Water Desalting Level I
8	10.0	$1,728	$0.00	1	Ocean Water Desalting Level II
9	0.3	$2,548	$0.00	1	Ocean Water Desalting Level III

Notes:

[1]**Up to 20 supply/conservation and 20 carryover options can be entered (only one carryover storage operation can be augmented, however, with put and take limits adjusted in proportion to the initial put/capacity and take/capacity ratios)**

[2]**Used to identify as storage or supply and to assign treatment and conveyance costs as well as for adjusting for demand hardening: 1: Regional Production, 2: Interior Conservation, 3: Exterior Conservation, 4: System Conservation, 5: Federal Service Contract Aqueduct Production, > 10 : Class of carryover storage being augmented + 10**

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Table A-3. Example Carryover Storage Operations File (*.stg)

Operation[1]	Capacity (TAF)	Init. Fill	Rech. Eff.	Put Limit (TAF)	Put Cost	Put Prty[2]	Take Limit[3] (TAF)	Take Cost	Take Prty[2]	Class[4]	Type[5]	Opr. Rule[6]	Description
1	220.0	100%	100%	220.0	$0	2.0	220.0	$0	6.0	1	1	0	Reserve Reservoir Operations
2	600.0	50%	100%	600.0	$0	1.0	287.0	$0	3.0	2	1	0	In-Region Reservoir Operations
3	195.0	50%	100%	56.0	$65	3.0	75.0	$65	3.0	3	1	0	IRP GW Program
4	267.0	50%	90%	66.8	$0	3.0	89.0	$81	5.0	3	2	0	Prop 13 & Raymond Basin GW
5	210.0	50%	90%	55.0	$94	3.0	70.0	$94	5.0	4	1	0	North Los Posas Banking
6	75.0	50%	90%	20.0	$0	3.0	50.0	$79	5.0	4	1	0	San Bernardino Banking
7	800.0	50%	90%	150.0	$0	6.0	150.0	$34	2.0	5	4	0	Colo R. Aq. GW Banking Operations
8	310.0	50%	90%	155.5	$81	5.0	125.0	$44	4.0	6	3	4	Kern-Delta WD & North Kern WSD
9	350.0	50%	90%	31.7	$35	5.0	31.5	$33	4.0	6	3	1	Semitropic WSD
10	250.0	50%	90%	100.0	$62	5.0	75.0	$45	4.0	6	3	2	Arvin-Edison WSD
11	285.5	0%	100%	285.5	$0	4.0	285.5	$0	1.0	7	0	5	SWP Carryover Storage

Notes:

[1]**LCPSIM code currently permits twenty storage operations to be entered.**

[2]**Highest priority = 1 (By default, LCPSIM uses dynamic priorities; these priorities may be used instead by selecting "Use Static Priorities" on the Main Screen).**

[3]**These limits can be used for take operations and are always used for calculating storage depletion for the purpose of making market transfers for recharge. If either a Type 1 or Type 2 operating rule is indicated, these limits are overidden by the rule parameters entered in the respective parameter files for take operations.**

[4]**Storage class ID:**

1: Reserve reservoir
2: In-Region reservoir
3: In-Region GW Storage
4: In-Region GW Bank
5: Federal service contract aqueduct GW Bank
6: External SWP aqueduct GW bank
7: SWP reservoir carryover

[5]**Used for conveyance and treatment costs for puts and takes:**

1: Conveyance to region for puts
2: Conveyance to region and treatment costs for puts (spreading of treated water for GW recharge)
3: Conveyance to SWP aqueduct bank for puts, conveyance from SWP aqueduct bank to region for takes
4: Conveyance to federal service aqueduct bank for puts, conveyance from federal service aqueduct aqueduct bank to region for takes
5: Conveyance to SWP bank for puts, conveyance from Delta for takes
6: Conveyance to region for puts, conveyance from federal service aqueduct for takes

[6]**Type of operating rule:**

1: Percentage Table A delivery take constraint
2: Consecutive use take constraint
3: Direct SWP SJV GW bank augmentation
4: Generic SJV storage
5: SWP carryover

Table A-4: Example Water Transfers Market File (*.mkt)

Source[1]	Amount Avail[2] (TAF)	Cost (Base) ($/AF)	Cost (Incremental) ($/TAF)	Conveyance[3] (Type)	Max Interval[4] (% of avail)	Max Sequential[5] (% of avail)	Deliv. Adj.[6] (%)	Description (AlphaNumeric)
1	650	$150	$0.00	4	1000%	200%	100%	Colo Riv Transfers
2	5,000	$160	$0.00	2	1000%	200%	100%	SV Ag Transfers
3	5,000	$268	$0.00	3	1000%	200%	100%	SJV Ag Transfers

Notes:

[1]Multiple transfer sources can be entered (up to 15)

[2]Available at source; overridden when time series transfer quantity files are found by LCPSIM. Time series transfer quantities are assumed either to be adjusted for losses or to be at the source (not adjusted for losses), based on the availability of time series delivery adjustment files (see Note 6, below).

[3]Used for capacity and operational constraints and conveyance cost calculations:
1: No transfer constraint or transfer costs
2: Sacramento Valley transfers
3: San Joaquin Valley Transfers
4: Federal service contract conveyance transfers

[4]Maximum amount that can be transferred over any ten year period

[5]Maximum that can be transferred in any two consecutive years
(If Max Interval is 1000% and Max Sequential is 200% then transfers are unrestricted)

[6]Adjustment for conveyance losses (e.g., Delta carrage water requirement); overridden when time series delivery adjustment files are found by LCPSIM. If found, time series transfer quantities are assumed be adjusted for losses, otherwise, they are assumed to be at source (unadjusted).

Table A-5. Example Water Market Year-Type Cost File (*.cst)

Type/Value	SV Base Cost ($/AF)	SV Inc Cost ($/TAF)	SJV Base Cost ($/AF)	SJV Inc Cost ($/TAF)
Wet	$135	$0.00	$182	$0.00
Above Normal	$135	$0.00	$196	$0.00
Below Normal	$135	$0.00	$206	$0.00
Dry	$151	$0.00	$281	$0.00
Critical	$175	$0.00	$281	$0.00
Driest Yrs Dry	$182	$0.00	$338	$0.00
Driest Yrs Critical	$210	$0.00	$338	$0.00

Note: Reflects higher cost to Sacramento Valley and San Joaquin Valley agricuture of forgoing supplies in drier years

Table A-6. Example Hydrologic Reliability Criteria File (*.hrc)

Criteria Step[1]	Shortage[2] (%)	Freq of Exceedence[3] (%)
1	15%	100%
2	10%	90%
3	0%	80%

Notes:

[1]Can be up to four steps

[2]Shortage threshold

[3]Maximum frequency with which a shortage exceeding the threshold occurs

Table A-7. Example Polynomial Loss Function File (*.ply)

Coeff #	Coefficient[1]
1	774.7503972
2	25154.31596
3	-16396.5462
4	-3527.78814

Notes:

[1]Coefficients of loss function polynomial (can be up to a degree 3 as is the example)

Table A-8. Example Percentage Delivery Constrained Take Rule File (*.pdc)

Rule Parameter	Value	Notes
Table A Allotment (TAF)[1]	155	1
Reserved Table A (TAF)[2]	22	2
Share of Bank (%)[3]	35%	3
Base Take Avail (TAF)[4]	31.5	4

Notes:

[1]SWP contract amount held by the agency operating the bank

[2]Amount of SWP contract quantity reserved for local use by the agency operating the bank

[3]Region's share of total bank capacity

[4]Guaranteed minimum take

The take limit for MWDSC from the Semitropic WSD bank is equal to the bank's pumpback capacity (Base Take Avail) plus the product of MWDSC's percentage share of the bank and Semitropic's SWP Contract Table A delivery after subtracting Semitropic's reserved amount of that allocation: Base Take Avail + Share of Bank * ((Table A Allotment * Percentage of Table A Delivered) - Reserved Table A)

Sources of information: MWDSC Staff

Table A-9. Example Consecutive Take Constrained Take Rule File (*.ctc)

Year No.[1]	Avaliable[2]
1	100%
2	75%
3	70%
4	60%
5	40%
6	0%

Notes:

[1]Consecutive take sequence year number

[2]Percentage of unconstrained take available

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LCPSIM Time Series Input Data Files

The following table contains a list of the hydrologic sequence time series data files used by the LCPSIM and the file naming conventions expected by the model. The base files are vectors (single columns) while the scenario files can be matrices with the columns representing different scenarios.

Table A-10. Time Series Data Files

File Type	Description	Data Source	File Naming Convention	
			Base Case[1]	Scenario[2]
Study ID	CALSIM study identification header text	Study name	*basefileid*.sid	*scnfileid*.sid
SWP Table A Delivery	CALSIM SWP Table A contractor deliveries	CALSIM II	*basefileid*.tba	*scnfileid*.tba
SWP Article 21 Delivery	CALSIM SWP Article contractor deliveries	CALSIM II	*basefileid*.a21	*scnfileid*.a21
Federal Contract Delivery	Deliveries based on federal water service contracts (e.g., CALSIM CVP contractor deliveries)	CALSIM II or regional model	*basefileid*.fcd	*scnfileid*.fcd
Regional Variable Supply	Regional supply unaffected by study scenarios	Regional model	*basefileid*.lvs	n/a[3]
SWP GW Augmentation	CALSIM GW augmentation deliveries	CALSIM II	*basefileid*.exb	*scnfileid*.exb
Total Transfer Limit	CALSIM water market total transfer capacities (quantities at source)	CALSIM II	*basefileid*.tlm	*scnfileid*.tlm
SAC Transfer Limit	CALSIM Sacramento Valley water market transfer delivery capacities net of losses	CALSIM II	*basefileid*.tsv	*scnfileid*.tsv
SJV Transfer Limit	CALSIM San Joaquin Valley water market transfer delivery capacities net of losses	CALSIM II	*basefileid*.tsj	*scnfileid*.tsj
SAC Transfer Factor	CALSIM Sacramento Valley water market transfer loss factors	CALSIM II	*basefileid*.fsv	*scnfileid*.fsv
SJV Transfer Factor	CALSIM San Joaquin Valley water market transfer loss factors	CALSIM II	*basefileid*.fsj	*scnfileid*.fsj
Table A Percentage	CALSIM agricultural contractor deliveries as a percentage of Table A contract amounts.	CALSIM II	*basefileid*.tap	*scnfileid*.tap
SWP Carryover Storage	Capacity for undelivered water to be stored by the SWP in San Luis Reservoir for delivery in the following year	CALSIM II	*basefileid*.slc	*scnfileid*.slc
Table A Turnbacks	SWP Table A deliveries assumed to be available due to inability to use them in another region	LCPSIM	*basefileid*.tat	*scnfileid*.tat
Article 21 Turnbacks	SWP Article 21 deliveries assumed to be available due to inability to use them in another region	LCPSIM	*basefileid*.a2t	*scnfileid*.a2t

Notes:
[1]These files must have the same primary file name (*basefileid*) and are required to be in the same directory.
[2]These files must have the same primary file name (*scnfileid*) and are required to be in the same directory.
[3]Applicable only if CALSIM generates different values for the scenarios.

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Selected LCPSIM Output Data

Table A-11. Summary Output Format

Annual Values / Increment >	Description of Results (Values are for least-cost solution operations)
Avg. Incremental Avail. Supply (TAF)	Average incremental supply made available to region by proposed project/program
Avg. Incremental Deliv. Supply (TAF)	Average amount of the incremental supply that region can currently consume or store
Avg. Inc. Dry Period Avail. Sup. (TAF)	Average incremental dry period supply made available to region by proposed project/program
Avg. Inc. Deliv. Dry Period Sup. (TAF)	Average amount of the incremental dry period supply that region can currently consume or store
Avoided Loss/Cost ($1,000)	Expected annual benefit of implementing proposed project/program
Total Loss/Cost ($1,000)[1]	Expected annual total costs and losses associated with shortage and regional options use
Shortage Loss/Cost ($1,000)	Expected annual shortage costs and losses
Regional Fixed Option Cost ($1,000)	Regression fitted annualized costs of use of regional options
Regional Total Fixed Option Use (TAF)	Quantity of supply/adjusted conservation from regional options
Regional Conservation Opt Use (TAF)	Quantity of conservation from regional options adjusted for reuse (net effect on supply required to meet demand)
Marg. Fixed Option Cost ($/AF)	Annualized cost of next increment of supply from regional supply options
Carryover Option Use (TAF)[2]	Size of capacity added to regional carryover storage
Carryover Option Cost ($1,000)[2]	Annualized cost of adding to regional carryover storage
Operations Cost ($1,000)	Cost of aqueduct conveyance, including wheeling of transfers and carryover storage, and other regional operations
Drought Shortage (90/91)	Shortage for the 90/91 drought period
Total Transfer Quantity (TAF)	Total quantity transferred over the hydrologic period
Ann. Avg. Transfer Quantity (TAF)	Average annual quantity transferred over the hyrdologic period
Total Transfer Cost ($1,000)	Total cost of transfers over the hyrdologic period
Ann. Avg. Transfer Cost ($1,000)	Average annual cost of transfers
(Output for each of the five water year types plus dry period and # of years represented)	
Water Year Type	Name of water year type or period
SWP Delivery (TAF)	Average SWP delivery
Federal Svc Contract Deliv (TAF)	Average federal service contract aqueduct delivery (e.g., CVP deliveries for the SF Bay Region)
Net Supply (TAF)	Average supply above current consumptive use
Unallocated SWP Delivery (TAF)	Average incremental SWP delivery not allocable to current consumptive use or regional carryover storage
Puts to Regional Storage (TAF)	Average puts to regional carryover storage facilities
Change in Storage (TAF)	Average change in regional carryover storage
Water Mkt Deliveries (TAF)	Average water market transfers
Net User Shortage (TAF)	Average user shortage after transfers
Total Loss/Cost ($1,000)	Average total costs and losses associated with shortage and regional options use
(Output for each regional option)	
Supply/Conservation Option	Name of regional supply/conservation option
Use / Reduction in Applied Water (TAF)	Quantity of supply from regional supply option or reduction in applied water use from conservation option
Cost ($1,000)[3]	Unfitted annualized cost of regional option use
(Output for each regional option)	
Carryover Storage Option[2]	
Use (TAF)	Size of capacity added to regional carryover storage
Cost ($1,000)[4]	Annualized cost of adding to regional carryover storage
(Output for each transfer source)	
Number of Transfers	Number of transfers during hyrdologic period
Quantity (TAF)	Total quantity transferred during hyrdologic period
Cost ($1,000)	Total costs of transfers during period of record
Avg. Quantity per Trf. (TAF)	Average quantity transferred per transfer event
Avg. Trf. Cost ($/AF)	Average unit cost of transfers
Frequency	Frequency of transfer evens during hyrdologic period

Notes:

[1]Sum of "Shortage Cost/Loss", "Regional Fixed Option Cost", "Carryover Option Cost" (if used), and "Ann. Avg. Transfer Cost"

[2]Will not be displayed if carryover storage options are not evaluated

[3]Sum of the costs for specific options will not equal "Regional Fixed Option Cost" displayed above as the specific option costs represent the individual products of the unit costs of the options and the least-cost solution quantities identified; the "Regional Fixed Option Cost" is a point on the cumulative option cost regression curve

[4]Sum of the costs for specific options will not equal "Carryover Option Cost" displayed above as the specific option costs represent the individual products of the unit costs of the options and the least-cost solution quantities identified; the "Carryover Option Cost" is a point on the cumulative option cost regression curve

Table A-12. Least-Cost Solution Summary Output Format

Net Supply	Description of Results (Values are for least-cost solution operations) (Output for each year in the hydrologic sequence, for the five hydrologic year types, for the dry period, and for the average)
Aug Net Supply	Supply available for delivery to carryover storage after netting out current year long-term conservation adjusted use target (negative value is deficit to be managed)
Resv Res Stg	Net adjustment to water balance from local long-term supply and conservation options implemented for least-cost solution
Rgnl Res Stg	Quantity of regional supply stored in reserve carryover storage
Rgnl GW Stg	Quantity of regional supply stored in within-region surface carryover storage
Rgnl GW Bank Stg	Quantity of regional supply stored in within-region groundwater storage
Cal Aq Bank Stg	Quantity of regional supply stored outside of region along the California Aqueduct in the San Joaquin Valley
Fed Svc Aq Bank Stg	Quantity of regional supply stored outside of region along the federal service contract aqueduct
Total Stg Change	Withdrawal from of regional supply carryover storage for current year use
Cntgcy Consv	Conservation required to help balance supply and use in current year during shortage events or triggered by unfavorable carryover storage conditions
IPGM Use	Scheduled interruptible program cutback to help balance supply and use in current year during shortage events
Base Use	Cutback in current year use over and above contingency conservation
Mkt Deliv Avail	Supply available for water market transfer based on conveyance capacity and third-party mitigation constraint rules
Mkt Deliv	Supply transferred to help meet current year use during shortage events
Pct Shortage	Cutback in current year conservation-adjusted use during shortage events
Short Losses	Economic losses from deliveries less than target long-term conservation-adjusted use
Sum Trf Cost	Available imported supply in excess of current year use and carryover storage stock or flow capacity for puts
Unused Supply	SWP supply available but not delivered because of regional use and carryover storage constraints
Sys Op Costs	Conveyance, distribution, treatment, and carryover storage operations costs for current year
Src CV Mkt Trf	Total uantity of Central Valley water market transfers at the source of the transfer
Cap Use Ratio	Ratio between regional carryover storage supply and current use
Take Call Ratio	Ratio between regional storage take carryover capacity and current use
GW Stg Aug Avail	Transfer supply available for recharging depleted regional carryover storage
GW Stg Aug Used	Transfer supply used for recharging depleted regional carryover storage
Total Puts	Total quantity used for puts to regional carryover storage (can exceed supply stored because of efficiency assumptions)
SWP Carryover	Quantity of regional supply allocated to SWP carryover storage in San Luis
Semitropic	Quantity of regional supply banked outside of region in the Semitropic Water Storage District
Arvin-Edison	Quantity of regional supply banked outside of region in the Arvin-Edison Water Storage District
Kern-Delta	Quantity of regional supply banked outside of region in the Kern-Delta Water Storage District
SJV Bank	Quantity of the regional supply banked outside of region in a hypothetical San Joaquin Valley groundwater banking operation
Src SAC Mkt Trf	Quantity of Sacramento Valley water market transfers at the source of the transfer
Src SJV Mkt Trf	Quantity of San Joaquin Valley water market transfers at the source of the transfer
Src FCD Mkt Trf	Quantity of water market transfers at the source of the transfer that are conveyed by the federal service contract aqueduct
Net SAC Mkt Trf	Quantity of Sacramento Valley water market transfers delivered to the region
Net SJV Mkt Trf	Quantity of San Joaquin Valley water market transfers delivered to the region
Net FCD Mkt Trf	Quantity of water market transfers delivered to the region that are conveyed by the federal service contract aqueduct
Net Shrtg Mkt Trf	Total quantity of water market transfers delivered for use during shortage events
Net StgRec Mkt Trf	Total quantity of water market transfers delivered for augmenting depleted regional carryover storage

Appendix B

LCPSIM Interface Screens

The following figures depict selected screens in the LCPSIM:

Figure B-1. Main Screen

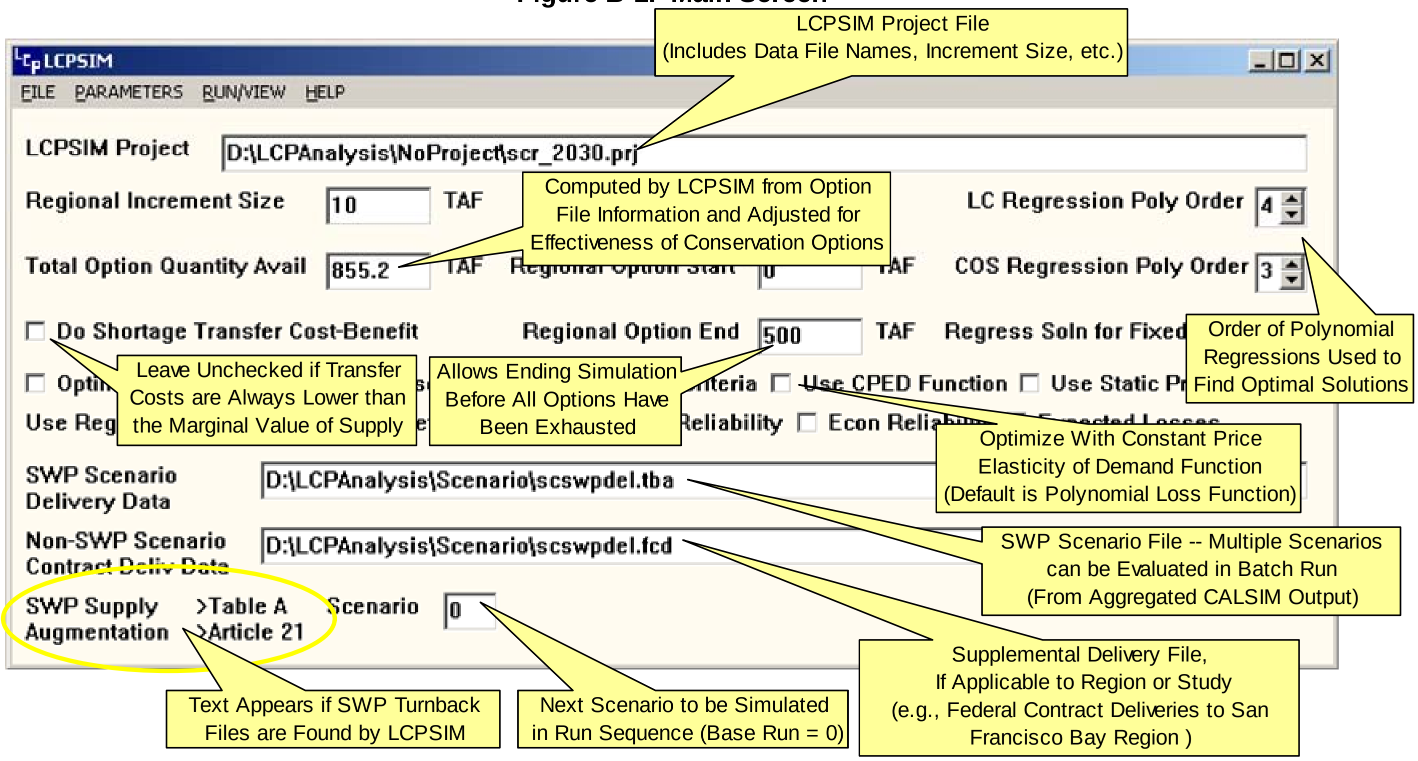

Figure B-2. Main Screen (Cont.)

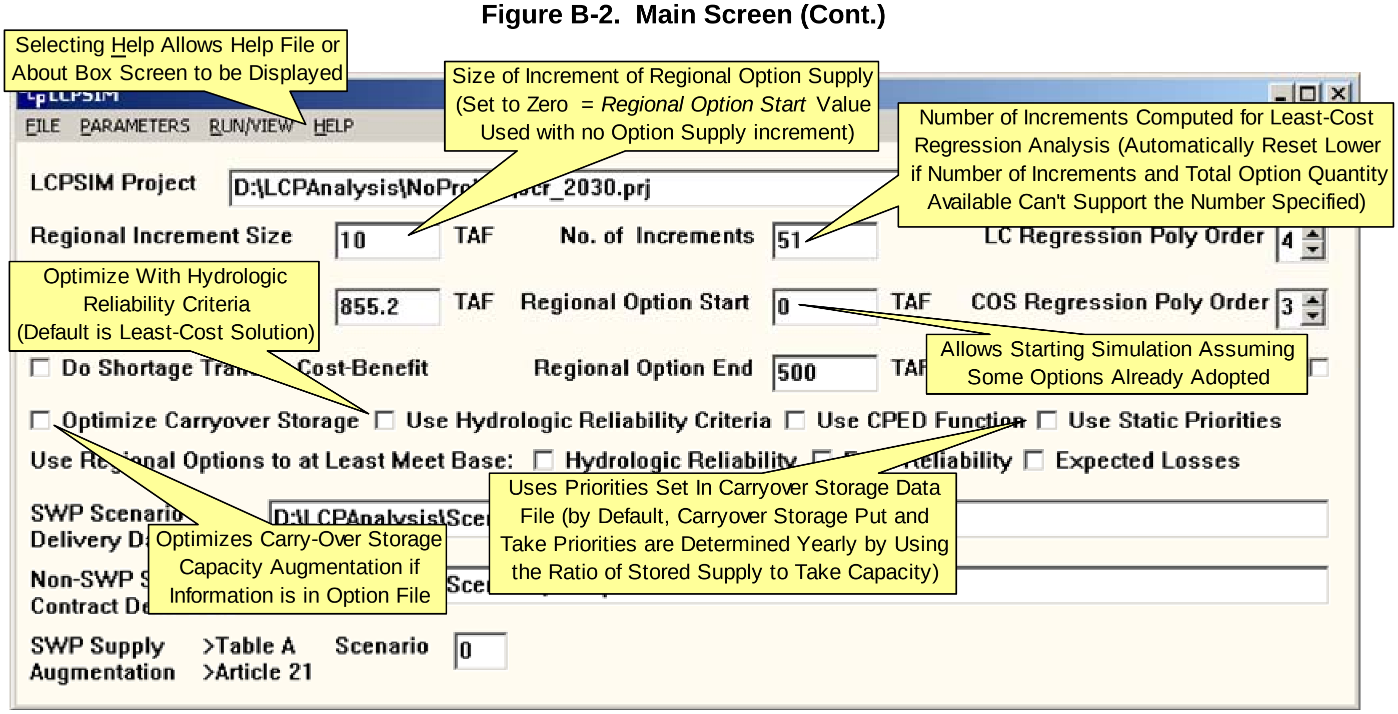

Figure B-3. Main Screen (Cont.)

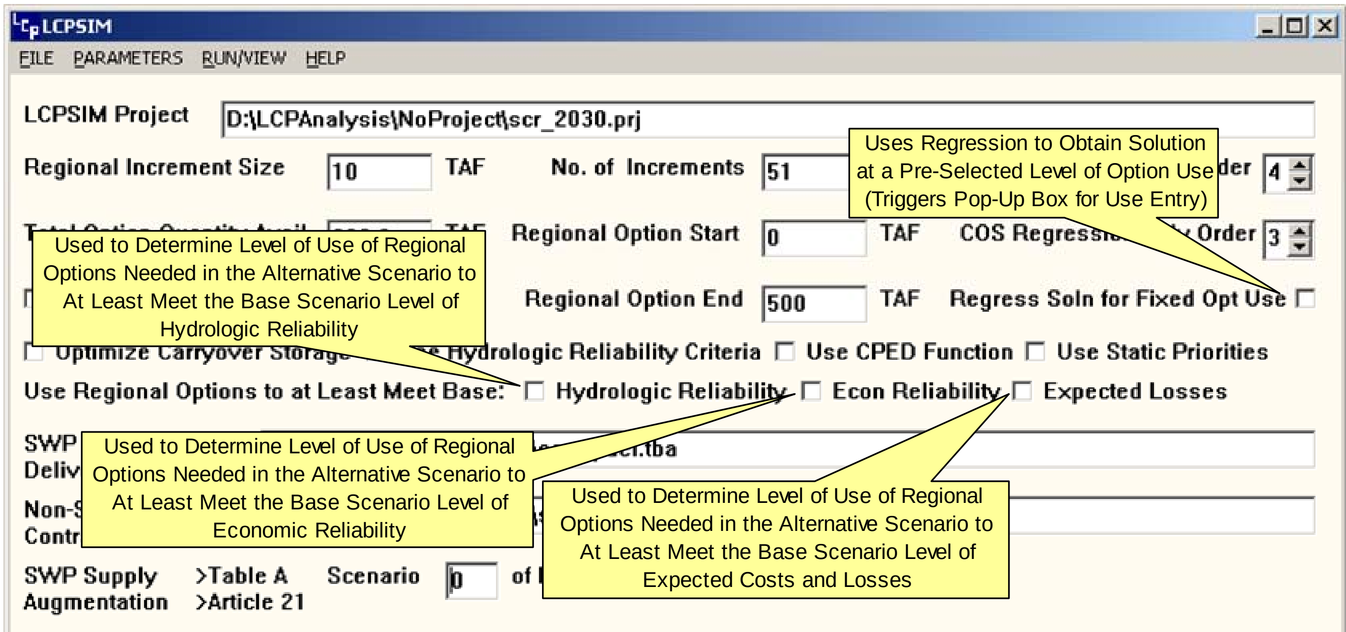

Figure B-4. File Menu

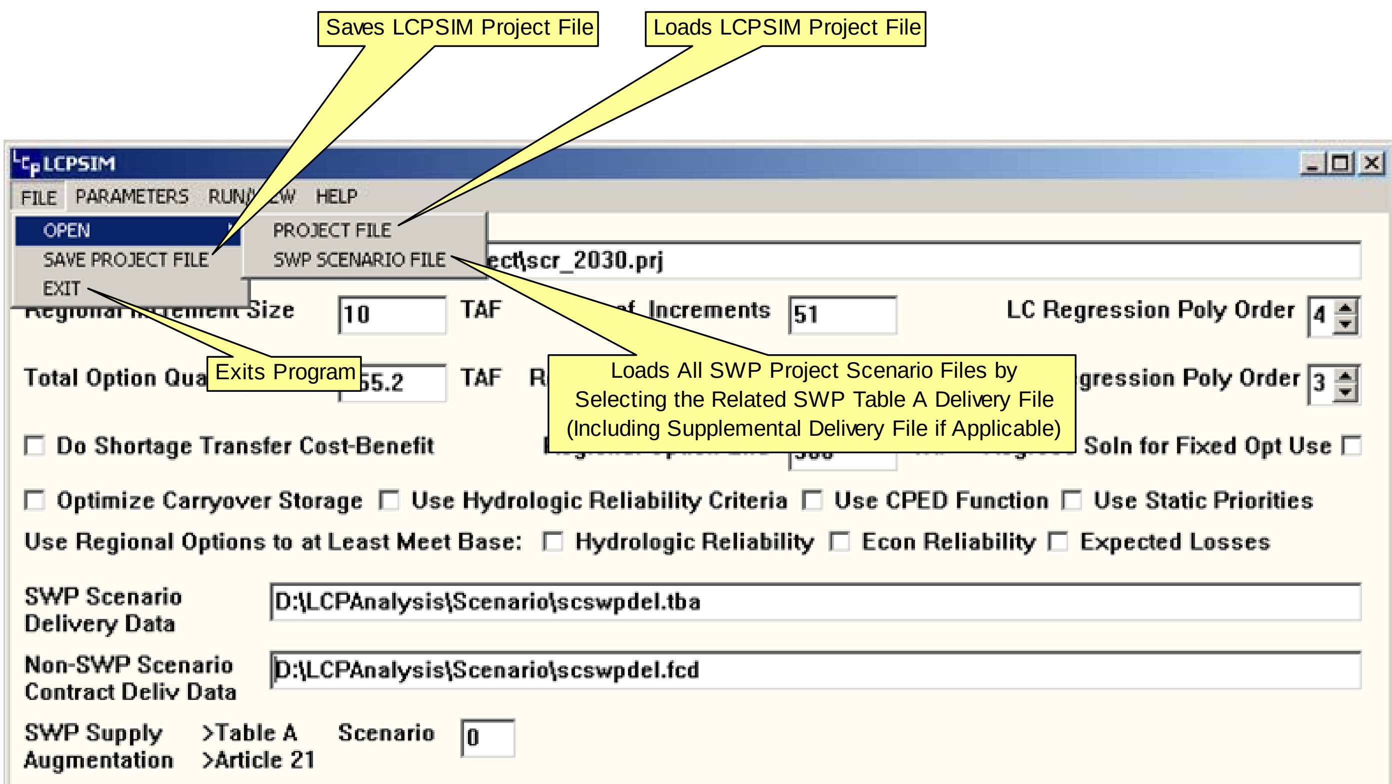

Figure B-5. Parameter Menu

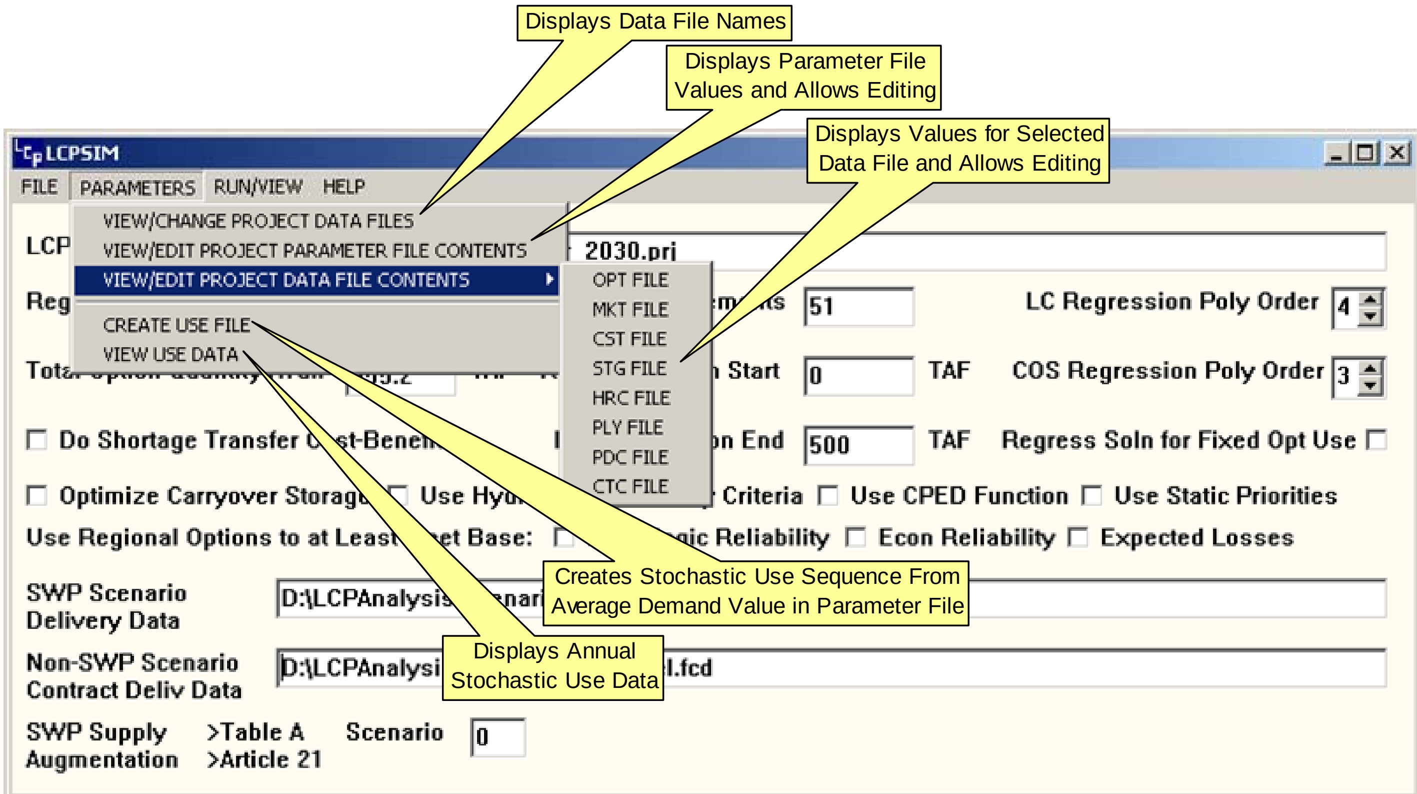

Figure B-6. Data File Screen

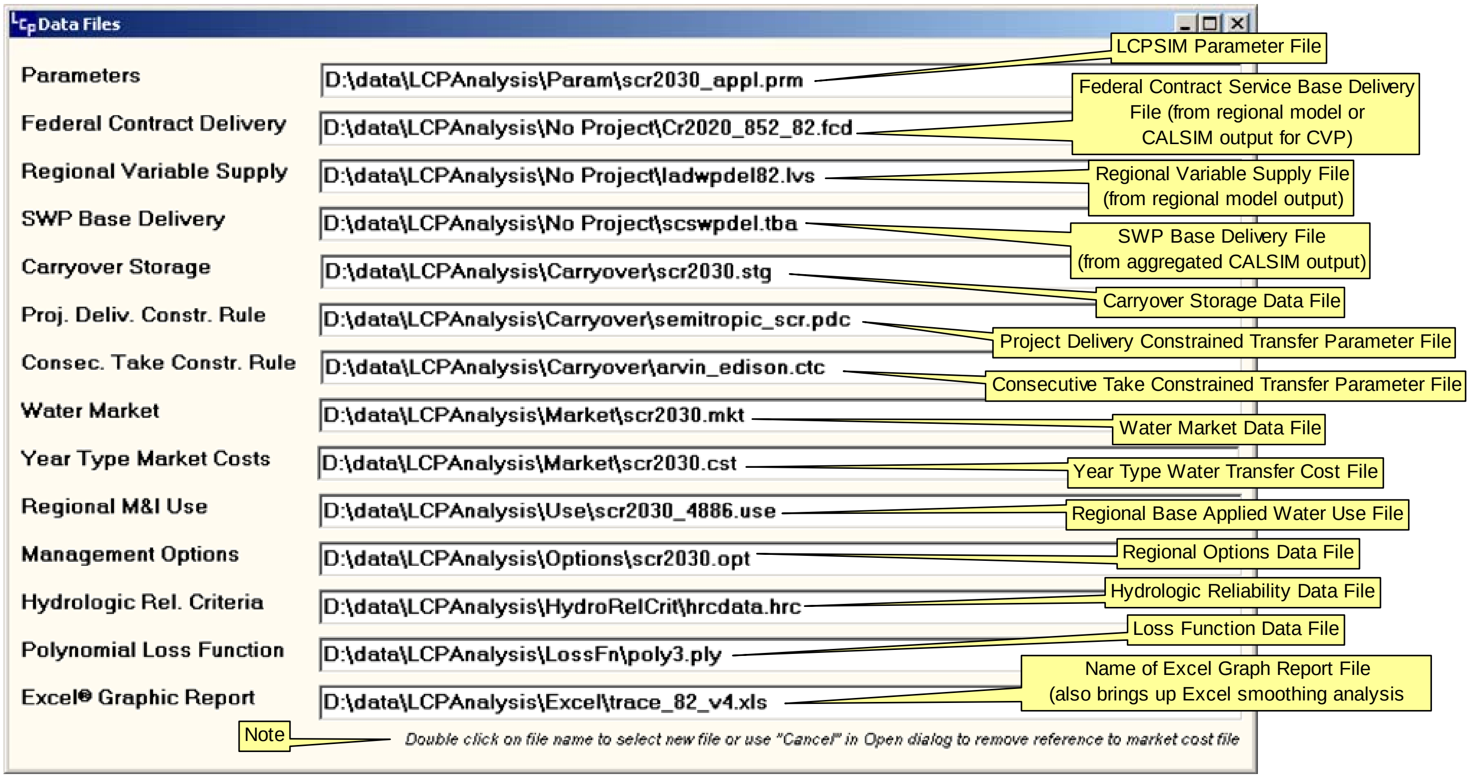

Figure B-7. Data File Edit Menu

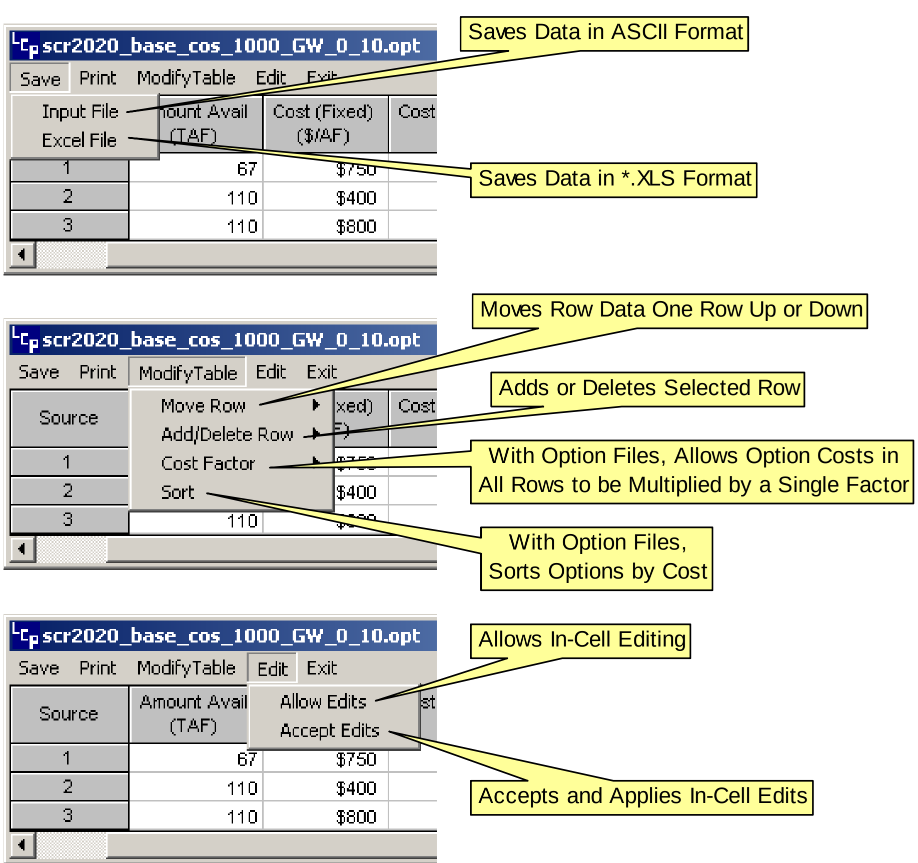

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Figure B-8. Run/View Menu

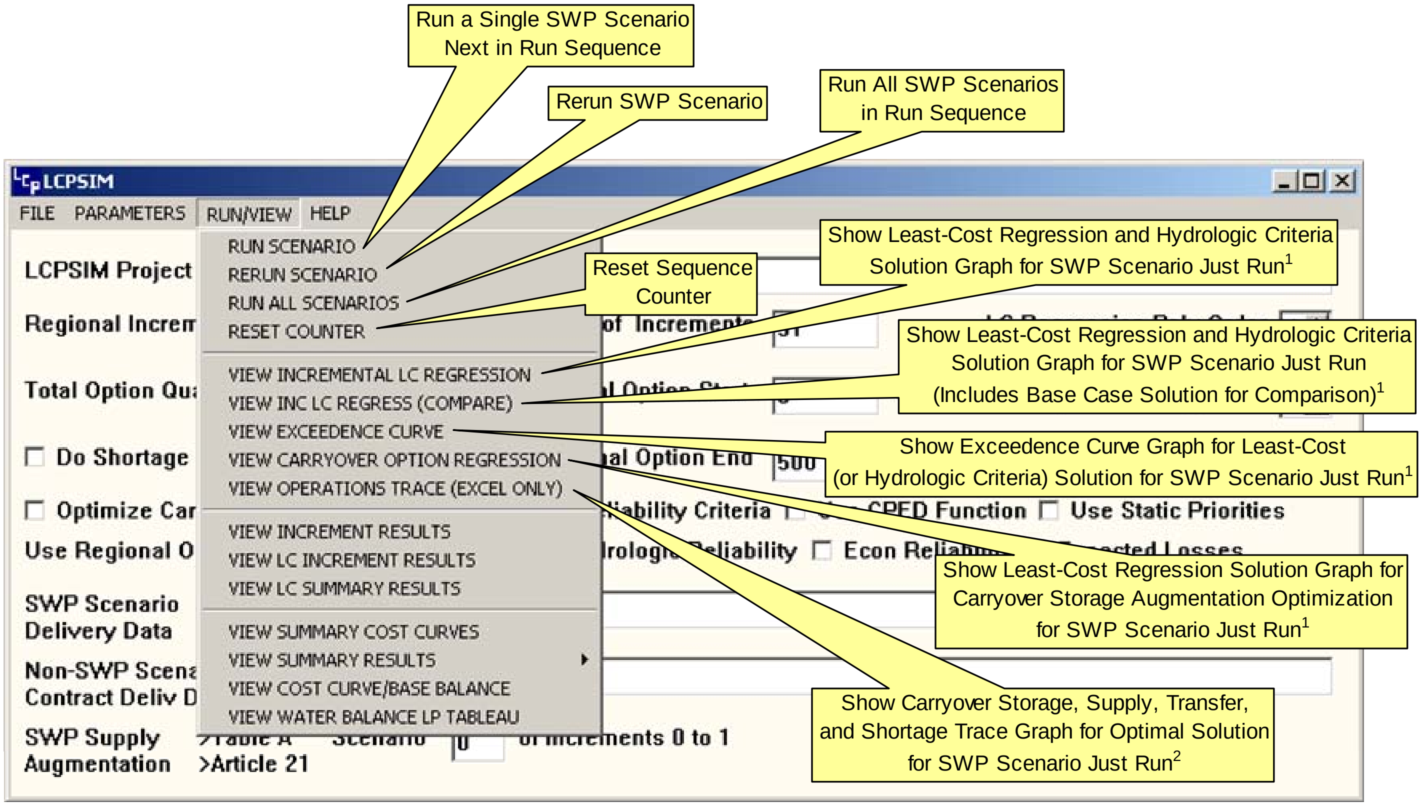


Figure B-9. Run/View Menu (Cont.)

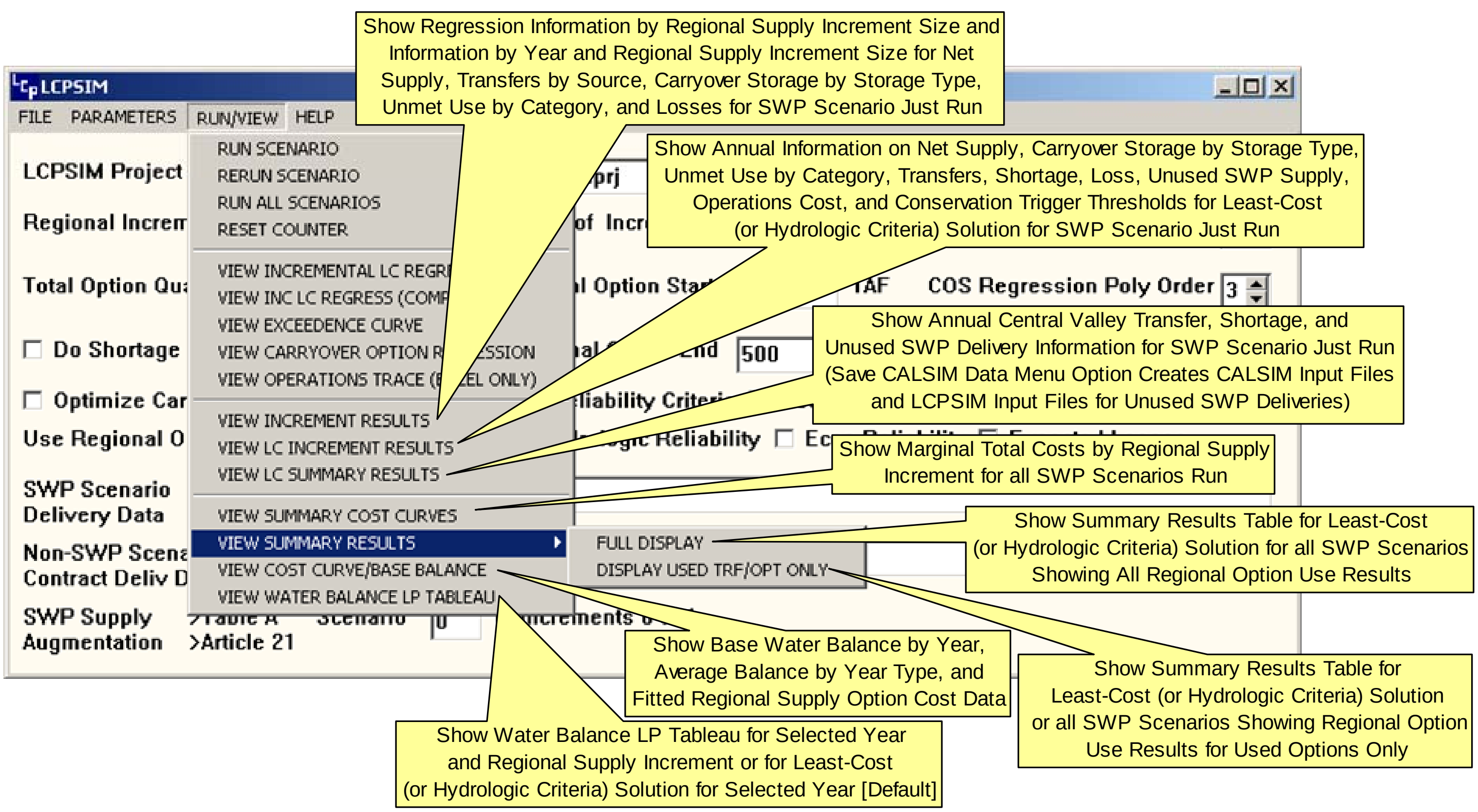


Figure B-10. Example Operations Trace Screen

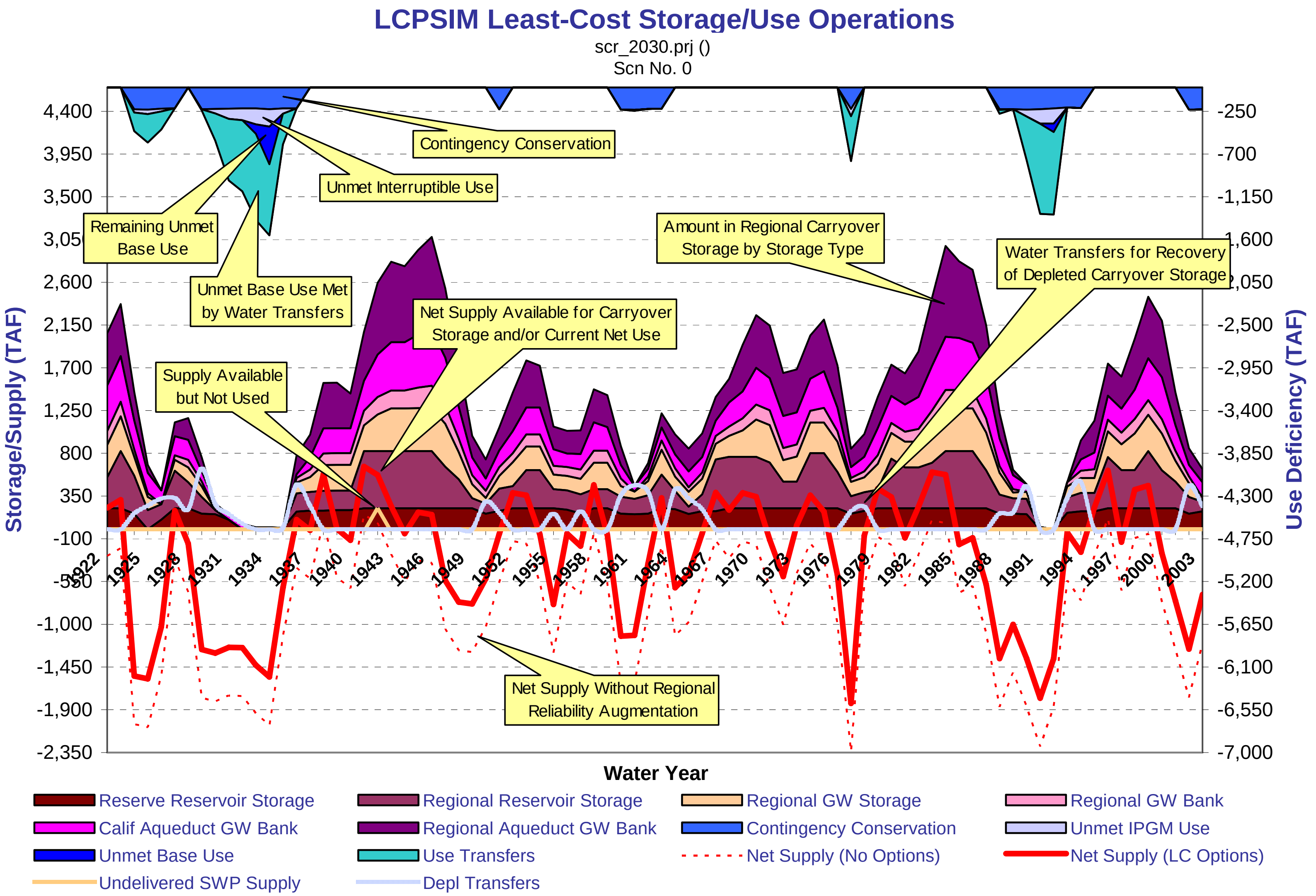
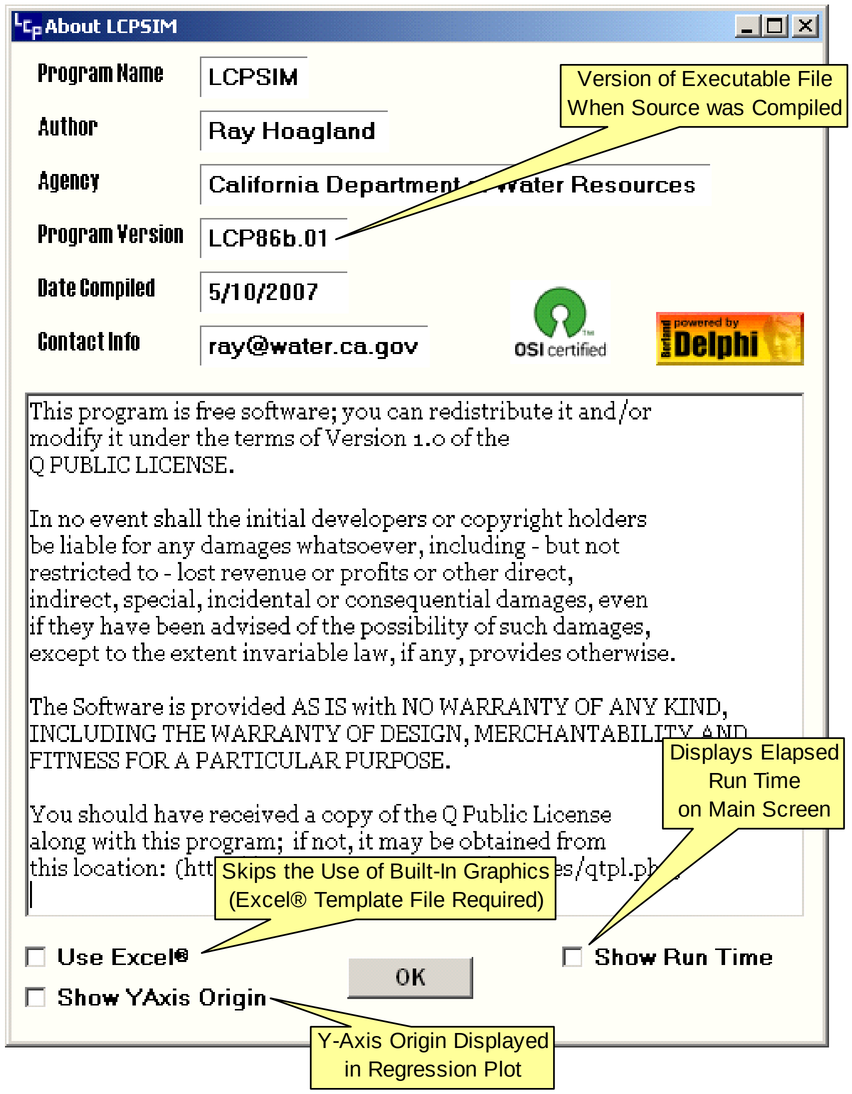


Figure B-11. About Box



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Appendix C

Smoothing Analysis Utility Screens

The following figures depict example screens in the Excel® smoothing analysis utility.

Figure C-1. Example Main Spreadsheet Screen

Smoothing Analysis

	startquan (TAF)	endquan (TAF)
range	600	900

	order
poly order	3

Polynomial Coefficients

	alt_coeff1	alt_coeff2	alt_coeff3	alt_coeff4	alt_coeff5	alt_coeff6	alt_coeff7	alt_coeff8
alternative	809.765715	-58.536988	-5.8739061	0.89713958	0	0	0	0
	base_coeff1	**base_coeff2**	**base_coeff3**	**base_coeff4**	**base_coeff5**	**base_coeff6**	**base_coeff7**	**base_coeff8**
base	287.426207	161.093276	-35.136466	2.17091769	0	0	0	0
	ben_coeff1	**ben_coeff2**	**ben_coeff3**	**ben_coeff4**	**ben_coeff5**	**ben_coeff6**	**ben_coeff7**	**ben_coeff8**
benefit	-522.33951	219.630264	-29.262559	1.27377811	0	0	0	0

	lc point (HTAF)	lc value ($Million)	Residual Variance
alternative	7.33	$418.41	19.39
base	7.49	$435.05	9.10
benefit		$16.64	21.76

Figure C-2. Example Smoothing Analysis Results Graph